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LEGUMES AND THE NITROGEN PROBLEM IN THE DRY FARMING AREAS OF WESTERN CANADA

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Authorities are in general agreement that land used for grain production, without the use of manure or fertilizers, gradually loses a portion of its nitrogen. There is also a general agreement that such a practice is agronomically unsound. Shutt (*6*) found that the nitrogen content of Portage la Prairie, Manitoba, soil, used in the production of grain crops for 25 years, changed from 0.651% to 0.506%. Similarly, soil from the Dominion Experimental Farm, Indian Head, Saskatchewan, in a period of 22 years showed a loss in nitrogen content from 0.317% to 0.254%. Expressed in pounds of nitrogen per acre in a soil depth of 8 inches the loss in the Indian Head soil amounted to 2,340 pounds from an initial total of 7,420 pounds. Subsequent investigation showed that this relatively rapid loss of nitrogen was not sustained, although the system of grain production had continued without change. Data secured some 16 years later even showed a slight gain in nitrogen. It would be incorrect, as Shutt points out, to assume that the heavy losses noted in cultivated soils are caused entirely by the grain crops. Analyses of these account for only one-third of the total loss observed. Alway (*1*) gives an example to show that soil, kept cultivated year after year without cropping of any description, may lose nitrogen as rapidly as that where fallow and crop alternate. The evidence at any rate indicates quite clearly that newly broken soil in Western Canada, cropped according to the practices common in this area, suffers an appreciable loss in nitrogen in a comparatively short time. The significance of this loss is not at present apparent. Western Canadian soils, according to reports of the Grain Research Laboratory, continue to produce wheat of high quality, particularly the soils in the so-called open plains section, where the major areas devoted to wheat production are located.

Field crops produced in the three western provinces of Manitoba, Saskatchewan and Alberta are essentially cereal crops, which are either sold off the farm or are used to form an important constituent in the rations of live stock. In 1928, the total area under cultivation in the three provinces was 51,118,128 acres. Wheat alone occupied 23,158,505 acres and the three major cereals, wheat, oats and barley, combined with cereal hays and summer-fallow, occupied an area of 47,107,267 acres, or 92% of the total cultivated area. The reason for this is not difficult to determine. Over extensive areas climatic conditions are such as to favour cereal production and to discourage other forms of husbandry.

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The present cultivated area of the three western provinces extends, roughly, for 800 miles east and west and 350 miles north and south with a broad belt centering on the Peace river in northwest Alberta. While grain crops are produced over this whole area appreciable differences in climate exist, chiefly with respect to precipitation, wind movement and evaporation. Generally speaking favourable moisture conditions exist over an area bordering along the east, north and west. This area comprises the so-called wooded and park areas to the east and north and the foothills country of the west. Within these limits lies the open plains area, which is centred in the province of Saskatchewan and is bordered on the south by the United States boundary. The Dominion Experimental Stations at Morden, Manitoba, and Lacombe, Alberta, are within the areas of favourable moisture conditions, while those at Scott and Swift Current, Saskatchewan, and Lethbridge, Alberta, are on the open plains. In these latter areas the system of dry-land farming is practised. The term "dry-land farming" indicates that under this system special precautions must be taken to conserve moisture as this is the limiting factor in crop production. Nearly two-thirds of the total cultivated area of Saskatchewan lies within the area in which dry-land farming is necessary, a lesser proportion in Alberta, and a relatively small proportion in Manitoba. Of the total wheat acreage of the three provinces about 60% lies within the area of dry-land farming. A scarcity of moisture here results in very low yields of wheat, although this is off-set to some extent by a high quality of grain. In the dry-land farming areas moisture conservation is by far the most important agricultural problem. It determines, in fact, the type of agriculture.

Some writers have professed to see in the practice of grain growing by Western Canadian farmers an irrational system of husbandry. It is believed that continued production of cereal crops will ultimately result in the exhaustion of soil fertility, and in support of this such factors as soil drifting, the menace of weeds and pathological difficulties are cited as evidence of an approaching condition when grain growing will be impossible. The recent studies of Kravkov (*5*), Tulaikov and Kuzmin (*7*), however, with reference to conditions in the cereal producing sections of Russia, which resemble those of Western Canada very closely, do not support this gloomy view. The yields of crops at present secured under relatively dry conditions cannot be taken as a criterion of the potential productive power of the soil.

When grain production forms the major farm activity supplies of farm manure are sufficient to replace only a fraction of the nitrogen lost during soil cultivation. Commercial fertilizers are relatively expensive, although the use of certain forms of fertilizer is increasing. The legume crops, which by the action of symbiotic bacteria are able to fix atmospheric nitrogen, have been hailed, therefore, as a cheap and convenient means of maintaining soil nitrogen and at the same time furnishing a supply of valuable fodder. Unfortunately these desirable results are not always realized. Legume crops are difficult to establish, in fact Gainey (*3*) points out that there are no legume crops well adapted for most semi-arid soils. When a stand of such crops is secured it is frequently at the expense of the yields of the cereals which follow.

The powerful influence of moisture in crop production under dry-land farming conditions is brought out in some soil moisture experiments conducted at the Swift Current station. In these experiments crops are grown in soil contained in deep water-tight tanks. The sole source of moisture supply for these crops is the natural precipitation, while conditions for growth are made to agree as closely as possible with those governing field crops. The use of deep tanks permits a very accurate check on moisture utilization, without affecting crop growth, by observing changes in weight of the whole equipment. In 1931 a series of similar three year rotations was begun. The rotation consists of: first year wheat seeded to sweet clover, second year sweet clover, third year wheat. The rotation is triplicated so that one sweet clover crop can be ploughed in mid-July, a second in mid-October, and a third in the following spring just prior to the seeding of wheat. Each year in the rotation is represented by duplicate tanks. The whole experiment is also repeated with Western rye grass in place of sweet clover. The influence of these crops on available soil moisture and this in turn upon the yield of wheat is indicated in Table 1.

TABLE 1.—WHEAT AFTER SWEET CLOVER AND WESTERN RYE GRASS. AVAILABLE SOIL MOISTURE AND YIELDS OF WHEAT. SWIFT CURRENT, SASKATCHEWAN, 1933

Sod ploughed	Available soil moisture		Yield of wheat per acre	
	Wheat after sweet clover, inches	Wheat after western rye grass, inches	After sweet clover, bush.	After western rye grass, bush.
July 15, 1932	4.42	4.59	19.4	18.2
Oct. 15, 1932	1.61	1.20	7.9	4.0
Spring, 1933	0.94	0.47	6.2	2.1

For convenience the above data have been expressed on a "bushels per acre" basis. Actually, of course, the yields of grain were quite small and were recorded as grams of grain. The utmost care was observed in harvesting these crops which were threshed by hand rubbing in preference to using any small machine. The conversion of grams per tank to bushels per acre was made by multiplying each result by a suitable factor, in this case 1.302.

In a standard three-year rotation of wheat, wheat and summer-fallow, also conducted with grain grown in tanks, the crop following summer-fallow yielded at the rate of 29.1 bushels per acre and that on stubble 11.0 bushels. The amounts of available water secured from the soil by these crops were 6.87 inches and 2.67 inches respectively. The term available soil moisture, as distinct from unavailable soil moisture, represents the amount of moisture present at seeding time which can be utilized by a growing crop. Most crops usually exhaust all available soil moisture during their growth, although the soil at harvest time still contains a very small amount termed the unavailable moisture.

Previous experiments have shown that, under prevailing conditions, no moisture is conserved in the soil as long as this supports a vegetative growth. The summer-fallow provides a most favourable means for moisture

conservation as the land remains bare for the longest period. Whatever contribution was made by the sweet clover towards soil improvement in this experiment, it was effectively masked, as the data indicate, by the moisture factor.

A somewhat similar experiment, discontinued in 1930, was also conducted with the use of soil contained in deep tanks. The rotation was of three years duration and consisted of wheat seeded to sweet clover, sweet clover hay, summer-fallow. With a period of summer-fallow intervening between the sweet clover hay and the wheat crops, there was an opportunity for the soil to conserve moisture and thus permit the favourable influence of the sweet clover to become evident. As in the previous example natural precipitation formed the sole source of moisture supply for the crops. Results of this experiment over a period of six years are given in Table 2. Data for wheat produced under similar conditions in a standard rotation of wheat, wheat, summer-fallow are included.

Table 2.—Wheat on summer-fallow. Swift Current, Saskatchewan, 1925–1930

—	Rainfall, inches	Available soil moisture		Yield of wheat per acre	
		Wheat after sweet clover, inches	Wheat after wheat, inches	After sweet clover, bush.	After wheat, bush.
1925	3.65	9.70	7.98	35.5	32.8
1926	6.00	6.94	8.24	36.6	44.9
1927	10.67	5.02	5.02	35.9	61.4
1928	7.63	9.74	9.77	63.7	59.9
1929	6.12	6.28	5.61	27.2	23.9
1930	4.83	4.19	4.55	20.2	25.4

In the standard three year rotation the fallow period, or period of moisture conservation in the soil, began immediately after harvest in August and proceeded for approximately twenty months. In the rotation containing sweet clover the length of the fallow period varied from season to season. Ordinarily the hay crop was harvested about one month before grain crops. It was then left to provide an aftermath. When this failed the soil had a longer time in which to conserve moisture; the process of ploughing sod has no appreciable influence on moisture conservation providing the soil is free of vegetation. On the other hand a continued growth of sweet clover effectively prevented moisture conservation until the crop was ploughed under.

The data bring out some very interesting facts. Wheat, in the wheat, sweet clover, summer-fallow rotation yielded higher than wheat in the standard rotation in 1925, 1928 and 1929. The yields of wheat secured in 1925 might possibly not be considered significant with the experiment conducted on such a small scale and also with such an appreciable difference in available soil moisture. Taking the above ground portions of these crops, however, that is to say, grain and straw combined, the evapo-transpiration ratios in this particular season were not appreciably different, being 471 for wheat in the sweet clover rotation and 481 in the standard

rotation. The total crop in the former case was 17% greater, but the grain yield was only 8% higher. Apparently the influence of the sweet clover was to lessen the proportion of grain to total crop. This influence appears to be quite marked in the 1927 results. Both crops secured the same amount of moisture, but the yields of grain were decidedly different. In this case the wheat from the standard rotation formed 40.4% of the total crop, while that from the sweet clover rotation was only 29.3%. A possible explanation for this difference may be found in a condition that has been frequently observed. A luxuriant growth of crop is usually indicative of a high transpiration rate. The transpiration from a growing crop of grain may, and usually does in dry-land farming areas, proceed at a rate much greater than can be maintained by the natural rainfall (*2*). Eventually soil moisture may be practically exhausted while the demands of the crop for moisture are still quite urgent. Under such conditions the potential yields of grain may be greatly reduced in a comparatively short time.

The 1928 season was perhaps the most favourable for crop production in the series. Soil moisture was abundant and this was supplemented by a normal amount of seasonal rainfall. The wheat crops in the two rotations utilized approximately the same amounts of water. The evapo-transpiration ratios were quite low, 342 for wheat in the sweet clover rotation and 364 for wheat in the standard rotation, indicating a remarkable efficiency in the use of water by the two crops. The proportion of grain to total crop, usually around 40%, was 33.1% in both cases. It is therefore quite possible that the yields indicate a significantly favourable influence from the sweet clover.

At the Indian Head, Saskatchewan, farm, wheat following alfalfa, in an alfalfa, summer-fallow, wheat rotation, yielded 24.7 bushels per acre as an average for eight years. In another experiment, conducted during the same period, wheat following summer-fallow in a rotation wheat, summer-fallow, wheat, yielded 33.5 bushels per acre. On the Lacombe, Alberta, station in a similar experiment wheat following alfalfa, but with a period of summer-fallow intervening, yielded as an average of nine years results 28.1 bushels per acre, while wheat on summer-fallow in the standard rotation yielded 32.0 bushels. The spread in the latter case is not very wide as one would naturally expect because moisture conditions at Lacombe are more favourable than those at Indian Head and more so than those at Swift Current. It is indeed surprising to find the influence of alfalfa upon soil moisture persisting over such a long period, but the work of Kiesselbach, Russel and Anderson (*4*) indicates that several years of complete fallow may be necessary under some conditions to restore soil moisture utilized by alfalfa.

The above rotations, wheat, legume, summer-fallow, while utilized experimentally, are not adapted to farmers' requirements in the drier areas. At the Dominion Experimental Stations at Morden, Manitoba, and Lacombe, Alberta, it is not uncommon to find sweet clover seeded with wheat to attain a height in the same season equal to that of the wheat plants. No such desirable results have been secured at the Swift Current and Lethbridge stations under the prevailing climatic conditions.

It may be urged with some justification that a supply of admittedly valuable forage should counterbalance the loss in wheat yields when

legumes and wheat are grown in succession. This, however, only holds in certain areas. Where the least depression in wheat yields occurs, through the action of previous crops in exhausting soil moisture, legume crops are successfully grown and give very satisfactory yields. Conversely legume and perennial hay crops are difficult to establish and give poor to only fair yields in areas where the moisture problem exists. Under such conditions farmers concentrate on the production of cereal crops, not because these offer promise of rich rewards for a minimum of physical effort—relatively low yields militate against this possibility—but because the practice ensures the most effective utilization of limited moisture resources. For his supplies of forage the farmer also relies upon cereals cut green for hay. On this point the 1933 issue of the *Guide to Saskatchewan Agriculture* comments as follows: "Where moisture is the chief limiting factor in the growth of forage crops, as it is in many parts of Saskatchewan, annual crops must necessarily play an important part in supplying the feed requirements for live stock. Perennial crops have their own sphere of usefulness, but annual crops are a more dependable source of forage, one year with another, since they may be grown on land which has a certain amount of reserve moisture. The relative importance of annual crops for hay and pasture increases as the moisture supply becomes more restricted". Annual hay crops it might be mentioned consist chiefly of oats, barley and rye. On the same topic the superintendent of the Scott, Saskatchewan, station in his report for 1930 remarks: "Annual hay crops continue to supply the large portion of cultivated forage crops in Northwestern Saskatchewan. They are more dependable and usually give fair yields". In brief, the areas in which annual hay crops are produced correspond to those in which dry-land farming is practised.

Conclusions

1. Extensive areas in Western Canada are utilized almost exclusively for the production of cereal crops.

2. Such a practice results in the loss of considerable amounts of soil nitrogen, although continued deterioration proceeds much slower beyond a certain point. Cereal production with restricted animal husbandry permits the return to the soil of only a small quantity of nitrogen by means of farm manure.

3. The valuable property of legume crops in indirectly replenishing soil nitrogen cannot be fully utilized under dry-land farming conditions as the moisture hazard restricts the growth of such crops.

4. The nitrogen problem, if such exists in the extensive dry-land farming areas of Western Canada, is destined to remain unless some radically new solution is found.

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RESUME

Les légumineuses et le problème de l'azote dans les régions de culture en terre sèche dans l'ouest du Canada. S. Barnes, Station expérimentale fédérale, Swift Current, Sask.

La production de céréales sans l'emploi de fumier ou d'engrais chimiques, résulte en une perte appréciable de l'azote du sol; cette perte s'est montée, dans un cas, à 2,340 livres pendant une période de 22 ans, sur un total, au début, de 7,420 livres. La culture des légumineuses est assez risquée, et l'aptitude spéciale qu'elles ont de restaurer l'azote du sol peut être paralysée par un manque d'humidité. Le blé cultivé après une jachère a donné 29.1 boisseaux; après du mélilot qui avait été enfoui à la charrue en juillet précédent, 19.4 boisseaux; après du mélilot qui avait été enfoui à la charrue en octobre précédent, 7.9 boisseaux, et après du mélilot qui avait été enfoui au printemps, juste avant les semailles du blé, seulement 6.2 boisseaux. L'effet favorable des légumineuses est de plus en plus apparent à mesure que la proportion d'eau dans le sol augmente.

NOTES ON THE LESSER BUDMOTH, *RECURVARIA NANELLA* HBN.

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The lesser budmoth, first recorded in Nova Scotia in 1915, was evidently quite numerous, at least in certain areas in the fruit district during that year. For the following twelve years the insect was more or less forgotten, due probably to insufficient numbers to attract attention. During the spring of 1927, when the writer was making a study of orchard insects, a few larvae closely resembling those of *Spilonota ocellana* D. & S., were noticed in the vicinity of Annapolis Royal. An attempt was made at this time to rear the larvae and carry the insect through its various life stages. This effort, however, was more or less a failure as the larvae all died before reaching maturity. The insect did not again attract the writer's attention until the spring of 1929, when larvae were frequently observed in various localities in the Annapolis Valley, with moderately infested orchards at Spa Springs and Berwick.

The life-history of *Recurvaria nanella* Hbn. is very similar to that of *Spilonota ocellana* D. & S. and the larva, at least in most of its stages, also closely resembles that of the more common and destructive budmoth. Due to the great prominence of the latter insect as an orchard pest in Nova Scotia at this period, a life-history study was made of *Recurvaria nanella* Hbn. and notes on its habits recorded.

ECONOMIC HISTORY

From a brief survey of the available literature it is evident that *Recurvaria nanella* Hbn. is a European species which is mentioned in entomological writings as early as 1776. In America, Scott and Paine report that the first specimens were obtained from Pennsylvania in 1903. Since that year it has been reported from various fruit growing States. In Canada, it has been reported from Ontario and Nova Scotia. In 1915, Dustan devoted some time to the life-history of this species in Nova Scotia, which was evidently the first record of its presence in the province. The larvae have been reported as feeding on apple, plum, apricot, pear, quince, peach, cherry and hawthorn. The writer has only observed the larvae feeding on apple, but no special effort was made to find it upon other host plants.

The various writers differ somewhat in their rating of the lesser budmoth as a fruit pest. From England it has been reported as feeding on pear and apricot, the latter crop being completely ruined in some instances. Records from Germany indicate that foliage of fruit trees became deformed to a pronounced extent. Other writers mention this species in a more or less casual manner, leaving the impression that it was a minor pest. Dustan found it common in Nova Scotia, at Kentville, but the resulting injury was apparently not of a serious nature. Unlike the eye-spotted

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budmoth, the larvae do not scar the fruit, and from the writer's experience there appears no cause to consider the lesser budmoth as a serious orchard pest. At the same time it must not be assumed that the larvae are not capable of causing much injury to fruit trees, especially to the buds in the spring of the year, should there be an increase to excessive numbers. As there are no records to indicate that this has so far occurred in Nova Scotia, *Recurvaria nanella* Hbn. must, for the present at least, be considered as a minor pest in the Annapolis Valley.

It may be further emphasized that the larvae are easily confused with those of *Spilonota ocellana* D. & S. and that fruit growers therefore should endeavour to avoid mistaking this species for the more destructive orchard insect.

LARVAE COMPARED WITH SPILONOTA OCELLANA D. & S.

The larvae of these two species of budmoths are present upon the trees at the same time, and although possibly not in corresponding instars are at least comparable in this respect.

It is during the first few weeks in the spring after emerging from their winter quarters that confusion is most likely to occur. At this time, however, it should not be difficult to distinguish characters with the aid of a hand lens which will in most instances separate and thus identify the larvae of these two species. The larvae of both species in the spring are brown, but those of *Recurvaria nanella* Hbn. are of a lighter shade, slightly mottled, with a decided velvety appearance and in size are somewhat smaller. The tubercles are smaller, less produced, and not rugose like those of *Spilonota ocellana* D. & S. The setae are shorter, finer and somewhat paler. Other writers have stated that the larvae lose their anal plate in the spring. From the writer's observations the anal plate at the last larval moult changes from a chocolate brown to a colour that blends so well with the body it is not readily distinguished from the surrounding surface. This change of colour is apparently what occurs and not an actual loss of the anal plate. In contrast, the anal plate of the eye-spotted budmoth remains dark brown throughout the entire larval period, so that when the lesser budmoth is observed in the last instar this constitutes a further distinguishing characteristic. As the larvae approach maturity confusion is less likely to occur, as the larvae of *Recurvaria nanella* Hbn. frequently assume a greenish or occasionally a brick-red colour and it is not unusual to observe a mixture or mottling of these two colours.

During the early instars of the lesser budmoth previous to its hibernating for the winter, the larvae are typical leaf miners, feeding entirely within the tissues of the leaf. In this respect they differ so strikingly from the eye-spotted budmoth that identity at this time is not difficult.

Pupa.—The pupa is less than a quarter of an inch in length, green when first formed but soon turning to a golden brown. It may be found at any location on the trunk or branches where rough bark is present. A favourite place is in the angle of limbs where some protection is afforded. It is well concealed under the loose bark in a small cell lined with silk. In this respect the location and cells in which it is found resemble those of the hibernating codling moth larvae. As previously mentioned, a few

larvae fail to desert the foliage and these pupate in their feeding positions, but this constitutes but a small percentage of the total.

The first pupa was found at the insectary at Annapolis Royal on June 19. It would seem that pupation commenced a few days earlier under natural conditions at Berwick, for on June 21 it was evident that somewhat more than 50% of the larvae had pupated.

From Table 4 it is evident that the pupal period lasts from twenty-four to twenty-seven days, with an average of twenty-five days for this stage.

LIFE-HISTORY AND HABITS

Adult.—The adults in 1929 began to emerge at Annapolis Royal from field collected pupae on July 8, and continued to emerge until July 30, or for a period of about three weeks. This appeared to parallel the emergence under field conditions, as one empty pupal case was observed outside on July 6, although no adults were in evidence for a few days later. On July 21 the adults at Berwick appeared to be at about their maximum numbers. In the cages males were the first to emerge, preceding the females by five days. At the close of this period females continued to appear four days after males ceased to emerge.

It was difficult to obtain mating and egg deposition under artificial conditions. The rearing cages were lantern globes placed over potted apple seedlings, but from nearly fifty matings only one female oviposited. In this particular cage a male and female were confined on July 8. On July 11 there were deposited 15 eggs, and during the following twelve days 39 more were laid, totalling 54 eggs. The female was dissected at death and 49 well developed eggs were obtained from the ovaries, making a total of 103 eggs. Two other females failing to oviposit were dissected at death and 74 and 81 eggs respectively obtained. Other females were examined but the eggs were so immature in the ovaries that accurate counts could not be made. These few records indicate that the egg capacity of the females probably varies from about 75 to slightly more than 100 eggs.

The female that oviposited in the cage died on July 29 and the male on August 1; the length of life of these mated individuals therefore, was 21 days for the female and 24 days for the male. In the other cages where no eggs were deposited the females lived from 20 to 25 days, and the males 19 to 22 days.

The adult's colour of grey and black endows it with a decided protective colouration, when in its natural habitat. The moths are usually found during the day at rest upon the trunks of the trees and blend so well in colour with the surrounding surface that they are difficult to distinguish. When disturbed they fly quickly away in a sort of circular flight, returning in a few moments, usually to the same tree, coming at rest again upon the trunk or dropping to the grass beneath. It is evident that this restricted flight prevents any rapid spread in the adult stage. This may be advanced as a factor for finding the insect very patchy in infested orchards. The adults were more active at night, but only feebly attracted to light.

In the course of the rearing work there was evidence of strong sexual attraction. The breeding cages were placed along one side of the insectory on a shelf about one foot from the outside wire screening. On July 14, eleven adults were captured on this wire outside and for the following six days from two to five were taken each day. These adults were all males and always resting on the wire at a point nearest to the caged females on the inside. This hardly seems a chance occurrence as the insect that year could scarcely be found about Annapolis Royal, and it appears that the males were attracted to the insectary by the females.

Eggs.—The eggs are only about one-sixtieth of an inch in length, somewhat cylindrical, and yellow in colour. In the breeding cages the eggs were laid under the bud scales, under the edge of next year's buds and a few at the base of the leaf petiole. They were deposited in groups, and under one bud scale 24 eggs were counted, but in most instances only 2 to 6 were found together. The eggs, although in contact, were apparently not adhering to each other. In the orchard the eggs were deposited upon the under side of the leaves near the larger veins, and on the leaf petioles. The eggs were placed loosely among the pubescence or hairs and apparently retained upon the foliage by this means. A careful search of the twigs revealed no eggs under bud scales, etc., as was found on the potted seedlings.

The incubation period is evidently about 23 to 24 days. Eggs deposited in the cage on July 11 began to hatch on August 4. The remaining eggs laid in confinement were deposited between the dates of July 11 and 23. The last larva to emerge from these eggs was on August 15. Taking into consideration the eggs laid on the last date would indicate an incubation period of 23 days.

Larva previous to hibernating.—For a few days before emerging the dark head of the larva can be observed through the egg shell, first as a dusky spot and later the head capsule becomes definitely outlined. The abdomen can usually be traced, but is very faint due to its pale colour. The tiny larva is seen curled up tightly within the egg, the head at the flattened end. A small rent is made in the egg shell from which the larva at once escapes. The larvae are at first less than one twenty-fifth of an inch in length, with a black head and pale body. Previous to hibernation for the winter they are typical leaf miners and in order to gain entrance to the leaf tissues a small circular portion is eaten in the more favoured positions between the veins on the under surface of the leaf. At first the mine is a more or less straight narrow trail but becomes widened and branched as feeding progresses. As these mines turn brown on the upper as well as the lower leaf surface infested foliage is readily located in the orchard. The small particles of frass are ejected from the mine and collect to a certain extent about the entrance. The head capsule at moulting is also usually ejected and frequently found adhering to the frass. After moulting either three or four times in the mines, the larvae desert the foliage to find suitable locations on the limbs to hibernate for the winter.

It was difficult to follow the larvae in the mines and obtain exact dates of moulting. However, daily records with reared larvae, together with observations in infested orchards, rendered it possible to obtain quite

Table 1.—Length of feeding period previous to hibernating of *Recurvaria nanella* Hbn., Annapolis Royal, N.S., 1929

Period of larval emergence	Period larvae hibernating	Length of indicated feeding period
Aug. 4 to 15	Sept. 7 to 28	34 to 44 days

accurate data in this regard. Larvae that hatched on August 4 ceased feeding on September 7. Likewise those hatching on August 15 deserted the foliage on September 28 to prepare winter quarters. These records coincided very closely with observations made outside under natural conditions. The first hibernaculum to be found in the orchard was on September 10 and the last larva observed hibernating was on October 3. The insect's most active hibernating period during 1929 was from September 15 to 25. Frequent measurements of head widths during the feeding period indicated that the larvae moult either three or four times before hibernating. The following is the average widths of head capsules of the early instars.

Table 2.—Total average width of head capsule including hibernating instar of *Recurvaria nanella* Hbn., Annapolis Royal, N.S., 1929

1st instar	2nd instar	3rd instar	4th instar	5th instar
.129 mm.	.178 mm.	.243 mm.	.293 mm.	.356 mm.

The hibernacula are to be found on the smaller outer limbs of the trees, under old bud scales or bits of loose bark, in fact most any favourable location except on the smooth bark. They are constructed of tightly woven silk which the larva spins about itself, covered on the outside with fine pellets of dark frass, and in outward appearance are much like those spun by *Spilonota ocellana* D. & S., although somewhat smaller and not so readily observed. Like the latter insect, the larvae moult when the hibernaculum is partly constructed. After hibernation was complete measurements were made of the head width, the results of which go to show that the winter is passed in either the fourth or fifth instar. The cast head was frequently broken or distorted, so that it was only possible to obtain accurate measurements in a few instances as noted in Table 3.

Table 3.—Width of cast head and of larvae in hibernacula *Recurvaria nanella* Hbn., Annapolis Royal, N.S., 1929.

Width of cast head	Width of head of larva in hibernaculum	Instar of larva in hibernaculum	Width of cast head	Width of head of larva in hibernaculum	Instar of larva in hibernaculum
.299 mm.	.388 mm.	5th instar	.227 mm.	.299 mm.	4th instar
Broken	.275 mm.	4th "	Distorted	.356 mm.	5th "
Broken	.291 mm.	4th "	Distorted	.308 mm.	4th "
.275 mm.	.340 mm.	5th "	.291 mm.	.356 mm.	5th "
Distorted	.332 mm.	5th "	Broken	.356 mm.	5th "
Distorted	.388 mm.	5th "	.291 mm.	.372 mm.	5th "

Overwintering Larvae.—The larvae in Nova Scotia begin to appear upon the buds in most seasons during the latter part of April. In 1927 they were observed on the buds on April 30, but emergence had begun at least a few days previous. In 1929 the first larva was observed working its way into a bud on April 25 and by May 5 practically all had deserted the hibernacula. Compared with *Spilonota ocellana* D. & S. in this respect, *Recurvaria nanella* Hbn. begins to emerge some few days earlier, and the period over which emergence occurs is not so prolonged. On May 5, when the larvae of the latter insect were about all within the buds, only about one-half of the former had emerged.

The larvae of *Recurvaria nanella* Hbn. upon emerging in the spring enter the buds at the tips if they have sufficiently expanded, otherwise they work their way through or between the bud scales and are soon obscured from view. Frass, green at first but soon turning brown, is cast out at the point of entrance and held loosely on the outside of the bud by a few threads of silk. In the early spring this frass is the only indication that the buds are infested. After the buds open the leaves are tied and held together with silk, thus interfering with normal development. The enclosed larvae frequently roll an inside leaf to form a close-fitting tube, and thus protected feed by skeletonizing the leaves within reach. The infested buds, blossoms and leaves as they appear upon the trees are so similar to those infested with the larvae of *Spilonota ocellana* D. & S. that a determination is impossible without opening and exposing the larva within.

There is a period varying from 50 to 72 days from commencement of feeding in the spring until pupation. This is an average of 56 feeding days. During this time the larvae apparently, from the data available, moult either two or three times. They were difficult to rear in confinement and the data gathered and given in Table 4 contains many gaps, with the result that only a few larvae were followed over this period with all details regarding moults. However, it appears that those larvae which hibernate as fourth instar moult three times, while those hibernating as fifth instar only moult twice in the spring. This is further substantiated by the fact

TABLE 4.—REARING RECORDS OF OVERWINTERING LARVAE *Recurvaria nanella* HBN.
ANNAPOLIS ROYAL, N.S., 1929

Date larva emerged from hibernaculum	Date first moult	Date second moult	Date third moult	Date larva spinning	Date pupated	Length prepupal period	Date adult emerged	Length pupal period
April 28	May 16	June 10	June 19	June 28	July 9	11 days	Aug. 2	24 days
April 30	May 25	June 10	(Disappeared June 4)					
April 27		May 20	June 4	June 7	June 19	12 days	July 16	27 days
April 30				June 7	June 24	17 days	July 19	25 days
April 27		May 14	May 25	June 4	June 26	22 days	July 23	27 days
May 3	May 24	June 17	(Dead in vial June 19)					
April 30	May 12	May 24	June 4	June 11	June 19	8 days	(adult failed to emerge)	
April 26		May 20	June 4	June 9	June 19	10 days	July 14	25 days
May 1		May 22	June 4	June 11	(Died on June 13)			
April 28	May 10	May 25		June 7	June 24	17 days	July 17	23 days
April 30	May 17	May 25		June 11	June 19	8 days	(adult failed to emerge)	
April 30	May 17	June 2		June 11	June 19	8 days	(adult failed to emerge)	
April 26			June 2	June 11	June 19	8 days	July 16	27 days
April 27			June 1	June 11	June 24	13 days	July 16	22 days
April 27			May 31	June 11	June 24	13 days	July 20	26 days
April 25			May 30	June 11	June 24	13 days	July 17	23 days

that many mature larvae gathered from outside were examined and head widths obtained, but in no instance were any of a sufficient width to be considered as an eighth instar. There is a pre-moult period lasting from two to six days when a delicate tube of silk is spun within which the larva is inclosed. At this time the larvae are inactive and quite helpless. After moulting they soon regain their former activity and feeding is resumed.

When mature the larvae desert the foliage and wander to limbs searching for suitable places to pupate. In a few instances they failed to desert the foliage, but pupated among the partly eaten leaves. A pupal case or cell of silk is spun and after a pre-pupal period of eight to as long as twenty-two days in some instances, the larvae change to pupa. The more advanced larvae begin to pupate about June 15 and for the following three weeks this transformation proceeds.

DAMAGE

Early injury to the developing buds, and the tying of the leaves and blossoms together preventing normal development are the injuries to be expected from this insect. For pronounced injury to the buds the insect must be present in rather large numbers, and except in a few very small areas this has not been known to occur in the Annapolis Valley. Even individual infestations are, as a rule, patchy, that is, in one part of the orchard the insect becomes prominent while a short distance away in another portion but few are found. The worst infested trees in 1929 and 1930 presented a ragged and somewhat unhealthy appearance at the first of the season. After the larvae become mature, the trees soon overcome this deformity of foliage and take on their normal appearance. The amount of leaf tissue consumed by the tiny larvae previous to hibernating apparently is of slight importance. Side injury to the fruit in the autumn, so common with many budmoths, does not occur, as the larvae do not come into contact with the fruit due to their mining habit.

PARASITES

Parasites were active during 1929 in all localities where this insect was found and were apparently quite effective in reducing their numbers. The parasites recovered included a braconid species and at least two species of ichneumon flies. Syrphid fly larvae were also observed attacking the larvae in the spring of the year. From many pupae collected in the orchard and kept in the insectary for adult emergence, neither moths or parasites emerged, and the writer has been unable to determine if this was due in any way to unfavourable conditions at the insectary preventing adult emergence or if parasites were present and these were adversely affected as well.

DESCRIPTION OF STAGES, RECURVARIA NANELLA HBN.

Egg.—Length .356 to .421 mm., width .210 to .259 mm. The egg when first laid is elongate, oval, not curved, rounded at ends and shining yellow in colour. Before hatching the egg at the micropylar end becomes slightly flattened with a number of minute projections which radiate longitudinally as fine pebbled ridges. These ridges may extend for practically the entire length of the egg, but more frequently only one-third to

three-quarters of this distance. The colour becomes duller as the embryo develops and a dull dark area finally appears at the micropylar end due to the colour of the developing head capsule of the larva.

LARVA

First instar.—Average width of head .129 mm. Total length of body .864 mm. Head pale brown, mouth parts slightly lighter than head, ocellar area black, setae short, fine and pale. Prothoracic shield dusky. Body pale yellow, including feet and prolegs. When viewed from above the caudal margin of each abdominal segment is whitish in colour; tubercles not distinguishable, setae short, fine and pale, anal plate chocolate brown.

Second instar.—Average width of head .178 mm. Total length of body 1.194 mm. Head black, not piceous, shining, ocellar area black; epistoma lighter than head, mandibles blackish; prothoracic shield dark olive green, slightly mottled. Body pale orange with a slight velvety appearance; feet and anal plate olive green, the latter somewhat mottled; spiracles difficult to discern.

Third instar.—Average width of head .243 mm. Total length of body 2.058 mm. Larva similar in appearance to previous instar except slightly darker in colour.

Fourth instar.—Average width of head .291 mm. Total length of body 2.593 mm. Head markings as previous instar. Prothoracic shield dark brown to black. Body a pale shade of brown ochre, with a decided velvety appearance; a small dark area on thorax equal distance from pro-shield and thoracic spiracle; spiracles very small, circular, and slightly produced; tubercles wanting, the short fine pale setae arising directly from the body wall, with a dusky circle at base; feet olive green, pale at joints; prolegs of the body colour with a narrow dusky band encircling the base; anal prolegs with a dusky area on dorso-lateral surface. When hibernating in this instar the larvae are contracted to less than 2 mm. in length.

Fifth instar.—Average width of head .356 mm. Total length of body 2.75 to 3.12 mm. The appearance of the larva in this instar is much the same as in the previous one.

Sixth instar.—Average width of head .455 mm. Total length of body 3.92 to 4.50 mm. Head markings are the same as in previous two instars. The body colour is a light shade of brown, slightly mottled with a velvety appearance. The tubercles are slightly produced, of the body colour. At the base of the setae is a small circle of darker colour than body. Chitinized areas of tubercles on abdominal segments 9 and 10 small and slightly darker than body. There are two in-curved hooks on each side of the anal opening; anal plate, as in all preceding instars, is a darker brown than the body surface.

Seventh instar.—Average width of head .567 mm. Total length of body 5.15 to 7.50 mm. Head black, epistoma lighter, brown; mandibles black; ocellar area black with transparent lenses; setae pale or rusty; short and fine. Body colour brown-ochre when first moulted; this colour is usually replaced with green or frequently a brick-red colour and it is not uncommon to find a mottling of these two colours. The larvae largely

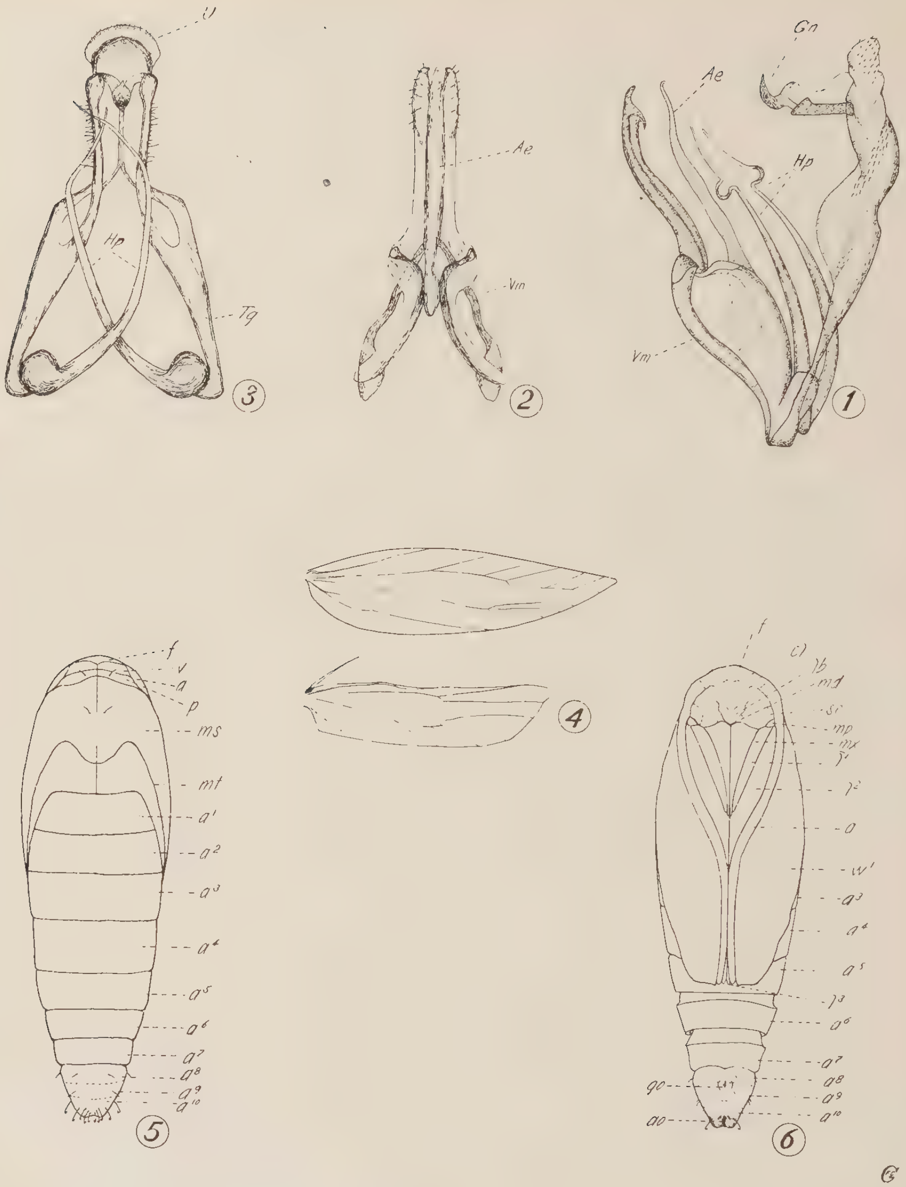

Plate 1.

LESSER BUDMOTH, *Recurvaria nanella* HBN.

1. Lateral view of male genitalia.
2. Ventral view of vinculum and aedoeagus.
3. Ventral view of tegumen and harpes.
4. Venation of wings of moth.
5. Pupa, dorsal view.
6. Pupa, ventral view.

Explanation of symbols applied to Genitalia—

Ae—aedoeagus.
Gn—gnathos.
Hp—harpe.
Tg—tegumen.
U—uncus.
Vm—vinculum.

Explanation of symbols applied to Pupa—

a—antenna.
a, 1 to 10—abdominal segments.
ao—anal opening.
cl—clypeus.
f—front.
go—genital opening.
lb—labrum.
l^1—prothoracic leg.
l^2—mesothoracic leg.
l^3—metathoracic leg.
md—mandible.
mp—maxillary palpus.
w^1—mesothorax wing.
ms—mesothorax.
mt—metathorax.
mx—maxilla.
p—prothorax.
se—sculptured eye-piece
v—vertex.

PLATE 2

1. Apple leaves showing mines caused by the young larvae previous to hibernating.
2. Apple leaves injured and tied together by the larvae after hibernation.
3. Winter hibernaculum in axil of leaf bud.
4. Pupae enclosed within the white cocoons on under surface of rough bark.

lose their velvety appearance in this instar. Tubercles slightly produced, of the body colour; setae as previous instar, the circle at base now changed to colour of body; feet olive green, pale at joints; prolegs colour of surrounding body surface, the dark markings at base of prolegs very faint or wanting. This applies as well to the dark markings on thorax and abdominal segments 9 and 10. Anal plate colour of body in contrast to a chocolate brown in all previous instars. The mature larvae vary from 7.5 to 9.5 mm. in length.

PUPA

The pupa is golden brown, segment 10 dark brown or black; pupal eyes either golden brown or black; clypeus, labrum and mandibles distinct; labial palpi entirely overlaid and concealed by the maxillae; antennae reaching to tip of wings; wings reaching to region of caudal margin fifth abdominal segment; spiracles small but distinct on segments 2 and 7; female genital opening a short dark slit, confluent with segments 8 and 9,

no adjacent elevations; male genital opening on segment 9, a dark slit with slight elevations; anal opening in both sexes a dark slit slightly depressed on extreme rounded end of segment 10; cremaster wanting; across dorsum and continuing slightly on venter is an irregular row of slender bristles curved at tips about midway on segment 10, approximately 12 in number.

ADULT

The adult moths of *Recurvaria nanella* Hbn. have a wing expanse of 11.5 to 12.5 mm. and in colour are a mixture of grey and black. A technical description by Busck of *Recurvaria crataegella* which is a synonym of *Recurvaria nanella*, is given in Proc. U.S. Nat. Mus. V, 25, p. 811, 1903. In the male genitalia the harpes, which are rounded, tapering organs, vary, in that some have a sharp twist or curve as figured in lateral view Plate 1, while in other individuals the harpes are only singly curved as shown in Figure 3 of the same plate.

RESUME

NOTES SUR LE PETIT PIQUE-BOUTON, *Recurvaria Nanella* HBN. F. C. Gilliatt, Laboratoire fédéral d'entomologie, Annapolis Royal, N.-E.

Ce petit pique-bouton est un insecte européen qui a été signalé pour la première fois en Nouvelle-Ecosse en 1915. Il se nourrit du feuillage du pommier et l'on dit qu'il s'attaque également à d'autres arbres fruitiers aux Etats-Unis. Cet insecte peut très bien être confondu dans le verger avec le pique-bouton ocellé. On ne considère pas que ce soit un fléau sérieux pour le moment, mais il pourrait très bien le devenir s'il augmentait d'une façon excessive. Les papillons font leur apparition vers la fin de juillet. Les œufs sont pondus sur le dessous des feuilles. Ils éclosent en août et les jeunes larves se nourrissent des feuilles qu'elles minent. Après plusieurs mues, en septembre elles quittent les feuilles et se transportent sur les branches extérieures, où elles passent l'hiver dans des refuges soyeux, couverts de fientes, sous les écailles des vieux bourgeons et l'écorce détachée. Au printemps les larves paraissent sur les boutons vers la fin d'avril et produisent un effet typique de pique-bouton sur le feuillage. Lorsqu'elles ont toute leur taille, elles se transforment en chrysalides, principalement dans les crevasses de l'écorce, vers la fin de juin, et sortent sous forme de papillons vers la fin de juillet.

QUANTITATIVE METHODS IN THE STUDY OF FOREST INSECTS[1]

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The various methods of studying forest insects referred to in this paper are essentially sampling methods, and some of them are quantitative in the broad sense of the term only. They may be conveniently divided into two principal groups: general population studies, and special studies of individual species or groups of species. The following is a concise account of some of the outstanding contributions in this field of research selected from the literature, and also of some experiments made by the author in the course of a study of the maple leaf-cutter, *Paraclemensia acerifoliella* Fitch.

General Population Studies

Very few general population studies have been made in the forest up to the present time. They are aptly referred to as animal community studies and are the work of ecologists rather than forest entomologists. Shelford and Sanders' *Quantitative and Seasonal Study of a Pine Dune Animal Community* (*9*) published in 1922 probably furnished the impetus and the inspiration for most of the work done subsequently on the animal communities of different types of forests. As such, it commands special attention both in respect to methods used and results obtained. The observations were made in 1914 in the dune region at the south end of Lake Michigan. The locality was a pine hollow in which jack pine was the dominant species. The method of collecting is described by the authors as follows: "The work was confined entirely to a study of quantity and of the correlation of local, especially vertical, animal distribution with temperature and evaporation. Collections were made and temperature and evaporation recorded in each of the levels commonly recognized, viz., ground, herbs, shrubs, and trees, between July 1 and August 30. This was done regularly every four or five days from all the levels at about 8.30 a.m. In addition, during two full days, the observations and collections were made in the various levels at intervals of four hours between 4.30 a.m. and 8.30 p.m. The ground collections were made where there were only scattered short-stemmed herbs. An actual count was made by forcing the open end of a bucket 25 cm. in diameter into the soil. By pouring a small quantity of a mixture of chloroform and gasoline through an opening in the inverted bottom, all the animals on the ground under the bucket were killed. It was difficult to see small insects such as aphids in the light soil. By using a fine sieve it was possible to obtain many which otherwise would have escaped observation. The other collections were obtained by making four strokes at each level with a close cotton net on a ring 30 cm. in diameter, with a handle 70 cm. long. To reduce the collections made with the bucket and net to the same value, sweeping with the net was followed in the same type of vegetation by bucket counting.

[1] Paper delivered at the Fifth Pacific Science Congress, Vancouver, B.C., June 1–14, 1933.
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It was found with a number of trials that *three* sweeps of the net yield essentially the same number of animals from the vegetation as one bucket counting. Three strokes with the net equal approximately .022 cubic meter of average denseness; four strokes equal .029 cubic meter."

In their summary the authors point out the difficulties inherent to a census of this kind, the seasonal variations in numbers, the variations due to physical conditions, the inward migration of animals breeding in adjacent areas and the upward and downward migrations at different periods of the day. They also state unequivocally that, "The accessibility of animals varies with conditions and makes collections with nets, etc., variable."

In 1924, Weese (*13*) published his *Animal Ecology of an Illinois Elm-maple Forest*. His method of sampling was fundamentally the same as that used by Sanders and Shelford. The unit area for his samples in the soil and leaf strata was 2 feet square. In the herb and shrub strata he adopted 10 short sweeps of the net. The net used was 30 cm. in diameter and each sweep about one meter in length; he calculated that 10 such sweeps included approximately the volume of vegetation above the unit area. No samples were taken in the tree stratum. The observations covered the period of one year and led the author to present certain correlations between fluctuations in the animal population and changes in environmental conditions.

This is the first large-scale attempt at a study of an animal community on land made in America and it contains much interesting information on stratal and seasonal abundance, inward and outward migration, seasonal succession, and the reactions and the rate of development of animals in gradients of environmental factors.

Two years later a comparison of the animal communities of coniferous and deciduous forests was published in the Illinois Biological Monographs by I. H. Blake (*2*). It contains an account of three studies of the synecology of land animals, the animal ecology of the upper slopes of Mount Ktaadn, the animal ecology of Maine pine-hemlock forest and the animal ecology of a deciduous forest in winter. With minor modifications, the methods used by Blake were practically the same as those of Weese and Shelford. A supplementary study published by Blake in 1931 (*3*) and an independent investigation by Smith (*11*) of the animal communities of the same deciduous forest as that studied by Weese and Blake in Illinois present no special interest from the standpoint of technique and methods.

Another important contribution to the quantitative study of animal communities in the forest is that by Bird (*1*). Certain minor changes in the method of sampling adopted by Bird are worth mentioning. The method was "essentially the same as that used by King (*7*) in his study of the prairie and early successional stages toward the aspen forest at Saskatoon, Saskatchewan." This method presents several refinements of the methods used by the authors previously mentioned. The time for making the collections was set at an early morning hour, at a period of minimum activity of the insects, thus insuring more accurate and possibly more uniform results. Such samples would, of course, not be suitable for the study of daily variations in stratal distribution but were well adapted for the investigation of seasonal succession. Three to five sweeps of the

net were used according to the density of the population. At the same time a sample was taken from the herb and surface strata by means of a metal cylinder 30 inches high and 14.13 inches in diameter. This cylinder was equipped with an iron band, 8 inches wide, sliding freely but closely over the outside of the cylinder. The place where a collection was to be made was approached quietly, and the cylinder was dropped open end downwards. The metal band was then forced a few inches into the ground and ether was poured into the cylinder through a hole at the top. After sufficient time had elapsed to anesthetize the insects, the cylinder was removed leaving the iron band in the ground. The insects found in the debris were gathered and, with the band still in the ground a soil sample was taken to a depth of 2 inches. A soil washer with two screens was used to separate the animals from the earth. It should be noted that the diameter of the metal cylinder 14.13 inches was chosen because the area of the circle enclosed represents 1/30,000 of an acre or 1/100,000 of an hectare. This measure greatly facilitates the calculation of the total population for any desired area.

In the work of all the above mentioned authors such an imposing array of interesting data is presented that little doubt can be entertained as to the validity of either the method used or the results obtained. In 1928, using similar methods, the author attempted a study of the animal communities of a maple-beech forest in the vicinity of Ottawa. Such striking variations and deficiencies appeared in our samples that it was necessary to forego the complete analysis of the data.

Special Population Studies

A large number of special population studies of a quantitative nature have been made by forest entomologists in the course of the regular performance of their duties. Nevertheless very little definite information with regard to the methods employed by the various investigators is available. This is particularly the case so far as the work of American forest entomologists is concerned, and is perhaps due to a kind of subconscious feeling on the part of the investigator that a detailed description of methods used on any special problem would probably be of little value with a view to its application to projects of another kind.

Whilst it is undoubtedly true that in formulating a method of study the particular nature and needs of a situation must be taken into account, it is equally certain that nearly all investigations have so many characteristics in common that the details of the methods used in a special study may be of great suggestive value in planning the work to be done on a similar or even a quite different type of problem. Among the European workers who have given considerable attention to the publication of methods in the study of special insect populations, we find Seitner in Austria, I. Trägårdh in Sweden, Z. S. Golovjanko and A. Iljinsky in Ukrania, and Unio Saalas in Finland. The work of these investigators will now be reviewed and a brief description will be given of some methods of sampling used by the author in studying the fluctuations in the larval population of *Paraclemensia acerifoliella* Fitch.

Since the mode of life of the insect studied largely dictates the technique of sampling to be employed, boring and leaf-feeding insects will be treated under separate headings.

A. Quantitative Methods of Studying Boring Insects

Seitner's Method of analysing bark-beetle populations

Logically as well as chronologically Seitner's (*10*) method of studying the fluctuations in the population of *Ips typographus* should probably be regarded as the pioneer work in the quantitative analysis of bark-beetle populations. This method will not be discussed here because the fundamental principles underlying it are evolved and perfected in various directions in the experiments of the other European workers described in the succeeding paragraphs.

Trägrådh's methods of studying the distribution and succession of species

At the International Congress at Zürich in 1926 Trägårdh (*12*) presented a paper in which he outlines a system of determining the relative economic importance of boring insects by an analysis of the selective tendencies exhibited by individual species as to the area attacked and also of the succession of the various species involved in the attack. Three principal methods are advocated: (a) Trap trees cut at monthly intervals during an entire year; (b) Analysis of dead or dying trees; (c) Sample plots. Trägårdh's principal contribution lies in his insistence on the necessity of making a thorough and complete analysis of entire trees, not simply of small sections of a tree, in his methods of representing graphically the results of analyses and in pointing out the practical value of such studies. The paper is too well known to require further comments.

Golovjanko's method of estimating infestations of the pine bark-beetle Myelophilus minor Hart

In his investigations of forests infested by bark-beetles, Golovjanko (*4*) used two methods, a rapid method, and a more thorough and detailed one. Nothing need be said about the first as it does not differ essentially from the ordinary preliminary survey usually made before control projects are attempted. The second method offers several points of interest as to the mode of procedure both in the collection of data and in their analysis.

A standing tree, which it is proposed to analyse, is marked near the ground with four marks corresponding to the four cardinal points. The tree is felled and divided longitudinally by means of lines drawn on the bark into four sectors corresponding to the marks previously placed at the bottom. Then it is cut transversely into sections one meter long. The logs or sections are numbered consecutively from the base upward and the numbers are entered on the analysis sheet with notes indicating to which region of the tree each section belongs, namely, the region of thick bark, the region of transition, the region of thin bark and the crown region. Then the circumference at the middle of each log is measured in centimeters. The number of centimeters in such a measurement is equal to the number of square decimeters in the superficies of the side of the log. Next the bark is carefully removed and an exact count is made of the beetle families present. This is accomplished by counting either the entrance tunnels or the nuptial chambers and in polygamous species the number of egg tunnels. In counting the latter the base of the egg tunnels only is used to prevent duplication arising from the presence of parts of egg

tunnels extending into the adjoining tree section. These data can be represented in a graph showing the successive meter lengths on the horizontal and the number of families on the vertical axis. This can be done either for the whole tree or for each sector and in the same graph the regions of the trunk can be indicated. Such a graph shows at a glance the distribution of various species in the different parts of the tree as well as the density of attack in any one area. (Fallen trees or trap trees are divided into sectors but not into meter lengths, each sector is analyzed as a whole. The sectors represent the upper, lower and lateral areas of the trunk.)

In the case of *Myelophilus minor* the curves of relative density of attack in the various meter lengths showed that the number of beetle families decreased toward the top of the tree. Two possible reasons for this decrease advanced by Golovjanko are that either the conditions for attack were less favourable in the upper part or that the decrease in numbers was due to the decrease in the diameter of the trunk. Apparently he does not consider the possibility of both these factors operating simultaneously. Hence he effects the exclusion of the second factor by determining the density of attack in terms of the average number of families per square decimeter. The data so obtained can then also be expressed in curves showing measures of length on the horizontal and measures of density on the vertical axis. Upon comparing such curves with curves of the number of families per meter length, it was found that, in the case of some insects *Ips acuminatus* for instance, the total number of beetle families decreases toward the top of the tree but that the relative density of attack increases. This proves that this particular species finds its optimum living conditions in the upper part of the tree.

For convenience in the construction of formulae Golovjanko devised a system of symbols representing all the important factors included in his study:

b—Average density of attack, *i.e.*, average number of families per square decimeter.

d—Average number of larval tunnels per family.

f—Per cent of larvae successfully completing their development.

l—Average number of families producing no young beetles at all.

c—Average number of exit holes (young beetles) per family.

p—Production, *i.e.*, average number of exit holes per square decimeter.

From a careful evaluation of these factors in his study of *M. minor* Golovjanko arrived at the following conclusions:

1. A decrease in the number of families means a decrease in the density of attack ("b").
2. A decrease in "b" is followed by (1) an increase in "d", the number of larval tunnels; (2) an increase in "f", the percentage of larvae successfully completing their development; (3) a decrease in "l", average number of families without progeny; (4) an increase in "c", the number of young beetles per family.

Golovjanko contends that only one factor production ("p") is independent of density of attack ("b") and that the more favourable the environment the greater will be the number of young beetles per family

provided the density of attack ("b") be the same. These conclusions apply only to *Myelophilus minor* and to the particular experiments from which the data were derived.

The following generalizations, which the author offers merely as likely working theories in the study of *M. minor*, are also proposed by him:

1. In pines which are identical as to conditions of temperature and susceptibility to attack, the value of "p" is practically a constant.

2. When "p" is a constant $\frac{c}{c_1} = \frac{b_1}{b}$; in other words the density of attack is inversely proportional to the average number of young beetles per family.

3. In a series of cases the ratio $\frac{c}{c_1}$ was found more closely proportional to $\frac{d^2}{d_1^2}$ than to $\frac{d}{d_1}$, from which we obtain

$$d_1 = \frac{d}{\sqrt{\frac{c}{c_1}}}$$

Hence, if we know the value of d for one area, we can calculate the same value (d_1) for another area. This formula however is not applicable except when $\frac{d^2}{c}$ = constant. A statistical analysis of the data shows that the variations of the value $\frac{d^2}{c}$ are not significant enough to affect the relations expressed by the formula. Golovjanko applied the above described method in testing the efficiency of trap trees as a control measure and arrived at some definite conclusions which, however, are outside of the scope of the present paper.

In 1928, A. Iljinsky using the method proposed by Golovjanko, analysed two lots of pines representing respectively 361 meters and 256 meters of tree superficies attacked by *Myelophilus minor*. This analysis produced the following results: For the entire 617 meters the number of beetle families was 82,054; the number of young beetles 310,136; and for the first 361 meters the larval tunnels totalled 852,893.

For each meter the following values were determined or calculated:

"A"—Number of beetle families per meter.

"M"—Number of larval tunnels per meter.

"O"—Number of exit holes (young beetles) per meter.

"q"—Superficies of each meter section expressed in square decimeters.

"b"—Density of attack = $\frac{A}{q}$.

"d"—Average number of larval tunnels per family = $\frac{M}{A}$.

"c"—Average number of young beetles per family = $\frac{O}{A}$.

"p"—Average number of young beetles per dcm.^{2} $= \frac{O}{q}$.

"e"—Average number of larval tunnels per dcm.^{2} $= \frac{M}{q}$.

"f"—Percentage of larvae completing their development $= \frac{100c}{d}$.

"l"—Percentage of beetle families producing no young beetles at all and

"k"—Percentage of families not having any larval tunnels at all.

These last two factors are determined by actual counts.

It is readily seen that p = bc and e = bd.

The next step consisted in classifying all meter lengths according to density of attack, determining the arithmetical mean for each class and the corresponding arithmetical mean for all other values. The correlation between the averages so obtained was then calculated. On the ground of these calculations Iljinsky constructs a number of formulae which, as they apply only to this particular experiment, cannot be thoroughly understood unless the tabulated data on which they are based be presented in full. He states very definitely that generalized formulae could only be proposed as the result of experiments conducted over a number of years.

In his general conclusions, Iljinsky differs from Golovjanko on only one point, namely, the independence of production ("p") from the density of attack ("b"). He shows conclusively that the density of attack is in itself a factor affecting the favourableness of the environment. Golovjanko's method and its elaboration by Iljinsky undoubtedly contain numerous suggestions which should be of considerable value in the study of bark-beetle populations in general.

Saalas' method of line or strip surveys in the study of the degree of infestation by forest insects

Saalas' (*8*) method of estimating populations is principally intended for use in the study of extensive areas infested by a number of species of boring beetles. In the sixteen forests examined by this method, the total length of the survey strips was approximately 28 kilometers. The strips were two meters in width and along their entire length every tree, living or dead, standing or fallen, and every stump were examined carefully. Notes were made of the diameter of the trees, the forest type, etc. A scale showing five degrees of infestation was devised.

I. One set of tunnels or a few scattered sets.
II. Distinctly less than half of the tree (or part of tree) covered with sets of tunnels.
III. Half the tree (or part of tree) covered with tunnels.
IV. Distinctly more than half of the tree (or part of tree) covered.
V. Nearly the entire area of tree (or part of tree) covered with tunnels.

By the expression "part of tree" in the above scale must be understood that particular area which any particular insect attacks under normal conditions. For instance, in the case of *Pityogenes chalcographus*,

if the degree of infestation assigned is V, this means that in a small tree with thin bark the entire area of the tree is covered with sets of tunnels, but when the tree is large only that part of the tree is completely covered with tunnels which has a thin bark, namely, the top of the trunk and the branches.

It is, of course, necessary to fell all standing trees for an examination of this kind and it is usually not difficult to assign the different trees to the degree class to which they properly belong. There is, however, some danger of overlooking trees belonging to class I.

The data obtained in the course of a survey are arranged in tables in such a manner as to give a clear picture of the conditions prevailing in the examined district. A number of such tables are shown in Dr. Saalas' paper. Only a small fraction of the first of these is reproduced here to give an idea of the system used in tabulating (Table 1).

TABLE 1.—STANDING DEAD SPRUCES

Species	Degree of infesta-tion	DBH. in cm.								Totals
		7–10	11–15	16–20	21–25	26–30	31–35	36–40	41–45	
		% of trees infested								
Hylurgops palliatus	0	100	100	33	50	33	33	17		41
	II							33	100	9
	III				20			17		9
	IV			67	30	67	67	33		41
Polygraphus sp.	0		100	33	70	67	100	83		66
	I					33				6
	II			33	10			17	100	13
	III			34	10					6
	IV	50			10					6
	V	50								3
Crypturgus hispidulus	0	100	100	100	100	83	100	100	100	97
	I					17				3
Xyloterus lineatus	0	100	100	100	40	33	33	17	100	47
	III				30	33		17		19
	IV				20	17	33	33		19
	V				10	17	34	33		15

This table explains itself; one sees at a glance that *Crypturgus hispidulus* is of rare occurrence, that all the other species shown were quite common, that one-third of the trees with DBH of 36–40 cm. were heavily infested (V) with *Xyloterus lineatus*, etc.

B. QUANTITATIVE METHODS OF STUDYING DEFOLIATORS

The quantitative study of defoliating insects presents many difficulties not encountered among the boring species. With the exception of the leaf-miners, they are free-living insects, many of them migrate over considerable distances, their distribution on the trees is often very uneven especially in moderate or light infestations, and many, moreover, live in the most inaccessible parts of the trees where any attempt at collecting

them in the ordinary manner creates a disturbance sufficient to invalidate the results of the sampling. For these and other reasons it has been the time-honoured custom to make the population studies of leaf-feeders during the resting (prepupal and pupal) stages, particularly if these insects come to the ground to complete their transformations. Since there are almost as many methods of accomplishing this task as there are investigators, it would be impossible to weigh the merits of the individual systems, and as most of them are quite limited in scope little would be gained from such a review. Probably one of the most interesting and far-reaching methods described in the literature is that used by A. Iljinsky (*6*) in the study of *Dendrolimus pini* L. Its main features will, therefore, be outlined below. It is quite evident that a population study conducted along these lines may furnish most excellent data upon which to base a prognostication of the probable general increase or decrease in numbers of a certain species and may serve as a guide in planning practical control measures. Nevertheless, it fails to give an insight into the numerous agencies at work throughout the entire life-cycle of the species in the rise and fall of insect infestations. To this end, it becomes necessary to study the vicissitudes to which the species is subjected from the moment of oviposition to the adult emergence of the next generation. As far as we have been able to determine very few such continuous investigations have been attempted in a quantitative manner in the realm of forest entomology. During the years 1928–1930 the author undertook such a study on the maple leaf-cutter population of a sugar-grove in the vicinity of Ottawa.

Iljinsky's method of estimating the larval population of Dendrolimus pini on the ground

The principal interest in this method attaches to the system employed in obtaining the required samples.

At first preliminary tests were made to ascertain the true distribution of the overwintering larvae in the debris. In a number of sample plots strips one-half meter wide were laid out in such a manner as to join the base of one tree to the next. All the trees in a plot were included in the experiment. The strips were then divided into meter lengths and the projection of the overhanging crowns was marked on the strip. For each meter length, *i.e.*, each half square meter, the number of larvae present in the litter was counted. Three test plots, containing 63 strips laid out between 61 trees, were examined. The strips varied in length from 1 to 26 meters. Tables were constructed with the strips arranged in ascending order according to their total length and the individual half square meter samples classified according to their distance from the trunk. The average number of larvae for each sample was then entered in its proper place. To give a better idea of this arrangement a small part of such a table is reproduced here (Table 2).

An analysis of the tabulated data showed that the greatest number of overwintering larvae congregated under the periphery of the crown. On the basis of this knowledge Iljinsky decided that to obtain a fair estimate of the population in his more extensive surveys it would be sufficient to count the larvae present at a distance of 2, 3, 4 and 5 meters in strips 4×0.5 meters located on that side of the tree on which the radius of the

Table 2.—Average number of larvae per 0.5 M² sample

Length of strips in meters	Distance of Samples from the Base of the Tree													Frequency or number of strips
	1	2	3	4	5	6	7	8	9	10	11	12	Etc.	
1	0.5													2
2	6.0	3												2
3	9.0	23	3											9
4	7.0	34	41	7										7
5	6.0	60	98	35	5									8
6	23.0	42	76	70	32	7								8
7	16.0	51	55	44	71	30	14							5
8	13.0	30	15	8	20	32	22	5						1
9	5.0	18	27	27	28	26	24	9	1					4
10	7.0	16	29	24	14	16	24	17	13	1				5

crown was the greatest. In discussing the merits of this system he states, among other things, that there is but little danger of overestimation since many larvae wander far beyond the periphery of the crown in search of hibernating quarters.

For the final estimate, it is necessary to calculate the number of larvae in relation to the area of the projection of the crown. This is done by multiplying the number of square meters in the projection by half the number of larvae in the two square meter sample. The calculated number of larvae per crown projection area approximated quite closely the numbers obtained from actual counts as may be seen from Table 3.

Table 3.—Comparison between actual and calculated number of larvae

Tree	Crown area meters²	Number of larvae in sample 2 sq. meters	Calculated number of larvae in crown area	Actual number of larvae in crown area
A	14.1	182	1283	1184
B	5.0	213	535	245
C	13.6	188	1278	1199
D	19.6	245	2391	1372
E	8.2	254	1041	517
Averages		216	1305	903

Before studying a forest, a general survey was made and the infested areas were mapped, the estimated intensity of each area being noted on the survey lines. Then the samples (4×0.5 meters) were taken on the survey lines in the different areas as follows: in the heavily infested areas at intervals of about 40 meters; in lightly infested areas at intervals of about 100–200 meters and, where the limits of the infestation were to be determined, at intervals of 20 meters.

The larval counts were made by eight women, working eight hours per day. They were able to count over some 14 to 24 samples daily, depending on the number of larvae present.

As the investigation progressed, the synopsis of the data reduced to averages per square meter was charted on a map by means of iso-lines showing the relative density of the population in the different areas. One type of line was used to delimit areas with an average of more than 100 larvae; another type, those with an average 50 to 100 larvae; and a third type, those with less than 50 larvae. Such a map makes it possible not only to appraise the conditions prevailing in the area studied, but also to estimate quite accurately what may be expected in the adjoining area.

A method of studying the progressive reduction in numbers during the active larval stages of Paraclemensia acerifoliella Fitch

Paraclemensia acerifoliella, a member of the family *Incurvariidae*, is a very common species which feeds on maple and, in some seasons, becomes very destructive in the sugar maple groves of Eastern Canada and the northeastern United States. Its general habits have been described by Fitch and by Herrick but these papers lack in several details which have a direct bearing on the present discussion, and it will, therefore, be necessary to preface this study of methods with a few words on some points in the life-history of the species.

Normally, the moths begin to fly during the last ten days of May; the peak of emergence is reached during the last days of May or the first days of June, and thereafter adult emergence continues at a rapidly decreasing rate until about June 15. The sex ratio is about 50 : 50. The female punctures the lower epidermis of the leaf and makes a small pocket in which a single egg is deposited. Upon dissection it was found that the ovaries contained from 100 to 120 eggs but it is probable that only about one-half or, at best, three-fourths of these are laid. The period of incubation is from 12 to 20 days. The newly hatched larvae live in an irregular serpentine mine between the upper and lower epidermis of the leaves. At the end of about six days the first moult takes place. The second stage larva continues to feed inside of the mine for a period of from three to five days, after which it cuts the first case. This case is made of a small rounded piece of the upper epidermis and a larger similar piece of the lower epidermis of the leaf cut out of the end of the mine. From that time on, the larva wanders about freely over the leaf surface carrying its case, the larger piece protecting the back of the larva and the smaller piece partly covering the lower part of the body. Wherever the larva settles to feed, the case is lightly attached to the surface of the leaf by means of silken strands. In the act of feeding, the front part of the body is protruded from beneath the upper cover and the leaf surface is skeletonized in a small circle around the periphery of the case. When most or all of the food within easy reach becomes consumed, the larva moves its case to a new location and the whole operation is repeated; the total number of feeding places varies somewhat from individual to individual. The second moult takes place within this first case, and the third stage larva continues to feed inside of it for a short time (1 to 4 days). Then the larva settles down in a chosen spot and proceeds to cut out of the leaf a new and larger cover for its case. When the cover is completed the larva moves the case away and continues its feeding operations as previously. The case now consists of the two epidermal layers cut out of the mine and of the newly cut piece of leaf

and in this paper will be referred to as the "second case". The small hole at the end of the mine where the first case was cut is referred to as the "first cut" whilst the hole left in the leaf where the new lid was cut will be called the "second cut". As time goes on, more cases, or rather new covers, are cut to accommodate the growing larva. All the larvae have six stages. Some of them cut five cases whilst others cut six. In a complete, normal life-history the last cover is of exactly the same dimensions as the larger piece of the case within which the larva was feeding up to that time. Feeding is no longer possible as the case is completely closed and inside of it the larva drops to the ground to pupate beneath the litter. A considerable percentage of the larvae do not cut this last fifth or sixth case and are quite able to pupate and hibernate successfully in their unfinished houses, provided they have completed the sixth stage of their development before dropping from the trees.

Briefly then, each completed larval life-history leaves the following traces on the surface of the leaves: (a) 1 mine; (b) 5 or 6 cuts gradually increasing in size; (c) a varying number of skeletonized feeding places corresponding in diameter to the size of case from which the feeding was done. The first case is cut by the second stage larva, the second case by the third stage larva and so forth, and the fifth case and also the sixth case are cut by the sixth stage larva. Although the sixth case appears to be supernumerary it should be remembered that a high percentage of the larvae construct such a case. Furthermore, since the various cases correspond quite closely to the different larval stages and since, to the practiced eye, it is a simple matter to distinguish the successive cases by their dimensions, it seems quite legitimate to use these cases as an index of larval development rather than the actual stages which cannot be identified except by tedious microscopic measurements. This has been our practice in the field experiments connected with this study.

In the fall of 1927, the attention of the Division of Forest Insects, Dominion Entomological Branch, was called to a severe outbreak of the maple leaf-cutter in a farm woodlot not far from Ottawa. Subsequent events proved that the infestation had reached its peak during the summer of 1927. There was a marked decline in 1928 and 1929 and the remnants of the population died out in 1930. The investigations were begun in the spring of 1928. During that year much time was devoted to the devising of appropriate methods, the analysis of the physical conditions of the habitat and to a general study of the life-history and habits of the insect. Much information was obtained, but it was not until the spring of 1929 that a systematic study of the causes attending the very noticeable reduction in population was attempted. It is needless to state that the experience gained during the previous season formed the basis of all the experiments undertaken in 1929 and 1930. Quantitative methods were used in all phases of the study: adult emergence, oviposition, embryonal development, larval development, reduction of the larval population and its causes, pupation and hibernation, fall and winter mortality, etc. In addition to these an elaborate system of physical measurements was maintained in operation at different points and different levels. All these experiments did not produce equally satisfactory results but, on the whole, a considerable measure of success was attained.

Only one of these experiments will be treated here in as concise a manner as possible, namely, the study of the progressive reduction of the larval population.

A method of simple or random sampling was used in the analysis of the larval population present on the trees. When the study was commenced in the spring of 1929, the infestation had dwindled to a notable extent, and, whilst practically all the trees were infested to a degree, the distribution of the insects on the individual trees had become quite spotty. Moreover, the relative density of the population varied in different parts of the grove. It was difficult therefore to establish a sufficiently uniform universe from which the samples were to be taken. After some deliberation it was finally decided to lay out a strip of plots 50′ × 50′ running diagonally from north to south through the grove. This strip would contain all the levels (290′ to 320′ above sea-level), all the different soil conditions, the principal conditions of exposure to wind and sunshine, a representative sample of the vegetation and a good cross-section of the infestation. The strip was 1550 feet in length and was divided into 31 plots. All the trees in it were numbered consecutively from north to south and an exact map showing their position and the projections of the crowns, was drawn. There were 237 trees in the plot representing all the principal species in the grove in the following proportions: maple 66%; beech 21%; ironwood 8%; elm 2%; linden 3%.

It was decided further that, the weather permitting, one sample would be taken every second day throughout the season under the following conditions and restrictions:

(a) 86 trees, selected as being particularly suitable for the work were to be used as the source of the component units of a sample.

(b) From each of these trees a twig, approximately 1½ feet in length, was to be cut at a height of from about 8 to 15 feet from the ground, this twig to be taken from the tip of a branch showing a fair degree of infestation.

The individual unit was analysed in the field and the following points were recorded in the note books under the number of the tree from which the twig was taken:

(a) Number of mines in which the larva had died.

(b) Number of mines from which the larva had cut its first case.

(c) Total number of mines.

(d) Number of 1st, 2nd, 3rd, etc., cases present containing living larvae.

(e) Number and kind of cases present containing dead larvae (cause of death if known).

(f) Number of feeding places.

Not until the experiment had been in progress for some time was it realized that very unfortunately the number of "cuts" had been omitted from this record. This constituted a very serious mistake which could not be remedied afterward. Whilst this omission affected the significance of the final results, it does not invalidate the method of sampling as such, as will be shown later.

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In all, 42 samples were taken between June 25 and September 18. The first of these samples had to be discarded owing to defects arising from inexperience. This leaves 41 samples between June 27 and September 18. Tables containing the complete set of data are too large for publication; we must therefore restrict ourselves to the final averages obtained from an analysis of the material at hand.

Average number of mines per sample, 123.

Average number of first cases based on five observations at the peak of frequency, 104.

Average number of second cases on same basis as above, 66.

Average number of third cases, 53.

Average number of fourth cases, 47.

Average number of fifth cases, 19.

(Sixth cases are rarely found as they drop from the trees as soon as constructed; it may be assumed that a large percentage of the larvae found in fifth cases cut a sixth case.)

If we assume that all larvae in the fifth and sixth cases and about 50% of the larvae which constructed fourth cases only successfully completed their development, the average number of survivors amounts to 32, or 26% of the larvae hatched from the egg.

As a check against the above experiment three station trees were analysed periodically. On each of these trees, 500 leaves, on branches satisfying the same general conditions as those set for the regular sampling, were marked with consecutive numbers. The numbers were written in India ink on the upper surface of the leaves, a fine camel's hair brush being used for the purpose.

The population present on the marked leaves was analysed once a week, the same system of notes being used as in the analysis of the plots with the one important difference that, in this case, the number and size of cuts was recorded as well as the number of the cases. The distance between tree A and tree B was 240 feet, and between tree B and tree C 150 feet; the infestation on tree B was somewhat heavier than on the other two trees. In the final comparison the averages for the three trees were computed. This gave the following figures:

Average number of mines, 147.

Average number of first cases, 120.

Average number of second cases, 76.

Average number of third cases, 53.

Average number of fourth cases, 46.

Average number of fifth cases, 24.

Final survival was calculated as for the previous experiment at 24%.

The difference, therefore. between the figures representing survival in these two independent experiments amounts to only 2%. Furthermore, the progressive stages of this reduction of the population parallel each other very closely as can be seen by juxtaposing the figures obtained in each analysis:

	Sample plots	Station trees		Sample plots	Station trees
Mines	123	147	Third cases	53	53
First cases	104	120	Fourth cases	47	46
Second cases	66	76	Fifth cases	19	24

These figures do not represent the true reduction in the population, because the number of cases found on the trees gives no indication of the entire number of cases actually cut. The figures given are merely adduced to show that the results of the two experiments with respect to a common factor are strictly comparable. This correspondence between the two experiments holds equally well in respect to a number of other phenomena, such as the dates of first appearance and of maximum frequency for each larval stage.

For the reasons already stated, it was impossible to use the data derived from the sample plot study to determine the true decrease in the number of larvae. This, however, could be easily done for the station trees and since the experiments were comparable in all other respects, it may be reasonably supposed that they would agree on this point also. The figures showing the absolute reduction present a very different picture from those showing the proportional reduction. They are based on the average number of mines and cuts counted on the station trees, and are as follows:

Mines	147	Fourth cuts	70
First cuts	120	Fifth cuts	65
Second cuts	96	Sixth cuts	8
Third cuts	79		

Assuming again that 50% of the larvae not advancing beyond the fourth case may be reckoned among the survivals as well as all the larvae in the fifth and sixth cases we find:

Number of larvae in the fourth case	70
Less larvae progressing to fifth and sixth cases	65
Number of larvae not progressing beyond fourth case	5
50% of 5 (roughly)	2
Number of larvae in fifth case only (65 − 8)	57
Number of larvae in sixth case	8
Total of survivors	67

$$\text{Per cent survival } \frac{67 \times 100}{147} = 45\%$$

All the figures gives thus far are for the year 1929. In 1930, we met with a new and entirely different set of conditions. The fall of 1929 and the early spring of 1930 were marked by a very heavy mortality among the prepupal larvae and the pupae on the ground. As a result, the spring population was confined to a small area of the grove and to a few trees

within this area. The sample plots used during the previous season were practically free from infestation and were no longer suitable for further studies. We were forced to use the station tree method in our work. The material for study was exceedingly scarce. Twenty trees were used; the individual samples varied considerably in size and contained in all 1000 numbered leaves. Although the results of this study have only an indirect bearing on the principal object of this paper, they present considerable interest inasmuch as they show the process of reduction of a severe infestation through its last stages. A summary of the principal features of the experiment is contained in the Table 4.

Table 4.—Progressive stages in the reduction of the population of *P. acerfoliella*
1930

Eggs:			Mines:		
	Hatched	789		Complete	641
	Unhatched	1135		Incomplete	148
	Total	1924		Total	789

Dates of analyses	Cuts						Cases present					
	1	2	3	4	5	6	1	2	3	4	5	6
June 22	14						14					
25	253						253					
28	393						391					
July 1	544	3					517	1				
4	607	37					517	41				
7	633	135					422	135				
10	639	261					277	264				
15	641	400					134	356				
18		446					72	361				
21		446	7				38	312	6			
24		468	56				16	247	52			
30		471	119				6	130	85			
Aug. 6		473	167	5			2	48	104	3		
13		475	174	19				19	89	17		
20			175	53				3	54	47		
27			176	61	2				18	41	3	
Sept. 3					8				4	18	9	
10					9					9	7	
17						2					1	1

Both the "sample plot" method and the "station tree" method seem to be well adapted to the study of the larval stages of *P. acerifoliella*. It should be remembered that this insect is sedentary in its habits. Many individuals complete their entire larval cycle on a single leaf; the average number of leaves visited by the larva in its migrations is about four and usually these are all close together. Migration being a factor of minor importance, the question of effective sampling is greatly simplified. The results obtained from the repeated analyses of stationary samples are not subject to the same amount of variation as those derived from sample plot studies but the labour involved is exceedingly tedious and requires vastly more time. For this reason it can be applied only to restricted areas and does not permit the investigation of many different conditions which may or may not affect the rate of development and the multiplication of the species.

The sample plot method, on the other hand, provided it be carefully planned, gives results which, for all practical purposes, are equally conclusive; it is more interesting, less laborious and has, above all, the decided advantage of being applicable to larger areas and a greater number of varying conditions. To give an idea of the variation met with in sampling according to this method, a statistical test was applied to the data collected in the sample plots in 1929. In the case of *P. acerifoliella*, the most suitable element for this test is the number of mines per sample. It marks the beginning of the larval life, can be determined throughout the season and, if the sampling is done properly in a well defined, uniform universe, should be fairly constant. In the tables constructed for the test, the 41 samples taken in 1929 were arranged according to the number of completed mines in 10 classes with intervals of 10 units per class. By using the mid-value of the class as a measure of variation we obtain the results shown in Table 5. In Table 6 the mean of the actual variations within the class limits was used and we arrive at practically the same conclusions.

TABLE 5.—MEASURE OF DISPERSION IN THE NUMBER OF MINES PER SAMPLE IN THE SAMPLE PLOT STUDIES*

Arithmetic mean = 104

Classes	f	m	x	x^2	fx^2	
60 – 69	2	65	39	1521	3042	Standard deviation = $\sqrt{\frac{\Sigma fx^2}{n-1}} = \pm 22.96$
70 – 79	5	75	29	841	4205	
80 – 89	4	85	14	196	784	
90 – 99	5	95	9	81	405	
100 – 109	9	105	1	1	9	Probable error = $.6745\sigma = \pm 15.47$
110 – 119	7	115	11	121	847	
120 – 129	3	125	21	441	1323	
130 – 139	2	135	31	961	1922	
140 – 149	2	145	41	1681	3362	
150 – 159	2	155	51	2601	5202	
Totals	41				21101	

TABLE 6.

Arithmetic mean = 104

Classes	f	m	x	x^2	fx^2	
60 – 69	2	65.50	38.50	1482.25	2964.50	
70 – 79	5	75.60	28.40	806.56	4032.80	Standard deviation = $\sqrt{\frac{\Sigma fx^2}{n-1}} = \pm 22.8$
80 – 89	4	84.50	19.50	380.25	1521.00	
90 – 99	5	94.50	9.50	90.25	451.25	
100 – 109	9	101.89	2.11	4.45	40.05	
110 – 119	7	113.45	9.45	89.29	625.03	
120 – 129	3	127.00	23.00	529.00	1587.00	Probable error = $.6745\sigma = \pm 15{\cdot}37$
130 – 139	2	131.00	27.00	729.00	1458.00	
140 – 149	2	142.00	38.00	1444.00	2888.00	
150 – 159	2	155.50	51.50	2652.25	5304.50	
Totals	41				20872.13	

*Only completed mines, that is to say mines from which first cases had been cut are included in Tables 5 and 6.

These tables show that if, as is customary for between 30 and 200 observations, we place the limit of rejection at four times the probable error, all the variations satisfy the requirements of normal probability. The final results of the two systems of calculation differ so very little that it seems advisable to use the first method only as it is somewhat simpler than the second.

In conclusion, may it be said that in the study of the maple leaf-cutter the above described methods produced very satisfactory results not only in determining the rate of decrease in numbers from stage to stage and from year to year, but in the analysis of many other biological phenomena. We have reason to believe that these methods, with the necessary modifications to adapt them to the individual problem, would produce good results in the investigation of other leaf-feeding insects with somewhat similar habits, such as leaf-miners and insects which feed gregariously.

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RESUME

Méthodes quantitatives pour l'étude des insectes des forêts. J. J. De Gryse, Division de l'Entomologie, Ministère de l'Agriculture, Ottawa, Ont.

Les différentes méthodes employées pour l'étude des insectes des forêts, et dont il est question dans ce travail, sont essentiellement des méthodes d'échantillonnage et certaines d'entre elles ne sont quantitatives que dans la signification la plus large de ce terme. On peut commodément les diviser en deux groupes principaux: Etudes de la population générale, et études spéciales d'espèces, prises séparément, ou de groupes d'espèces. Il ne s'est fait jusqu'ici que très peu d'études de la population générale. C'est plutôt là un travail pour les écologistes que pour les entomologistes des forêts. On les a justement nommées des études de la communauté animale.

Les entomologistes forestiers ont fait un grand nombre d'études spéciales de population d'une nature quantitative, mais il n'existe encore que très peu de renseignements précis sur les méthodes employées par les différents investigateurs. Parmi les chercheurs européens qui ont donné beaucoup d'attention à la publication des méthodes employées dans l'étude des populations spéciales d'insectes: nous trouvons Seitner en Autriche, I. Tragardh en Suède, Z. S. Golovjanko et A. Iljinsky en Ukraine et Unio Saalas en Finlande. Les travaux de ces chercheurs sont passés en revue, et à la fin de l'ouvrage, certaines méthodes d'échantillonnage pour l'étude des fluctuations de la population larvaire de *Paraclemensia acerifoliella* Fitch. sont décrites quelque peu en détail. La méthode de "parcelles d'échantillons" et celle "d'arbre de station" paraissent bien convenir à l'étude de cet insecte dont les habitudes sont très sédentaires. Beaucoup d'individus complètent tout leur cycle larvaire sur une seule feuille; le nombre moyen de feuilles visitées par la larve dans ses migrations est d'environ quatre et généralement toutes ces feuilles sont près l'une de l'autre. Comme la migration est un facteur d'importance secondaire, la question de l'échantillonnage est grandement simplifiée de ce fait.

FIELD EXPERIMENTS ON THE PREVENTION OF CEREAL RUSTS BY SULPHUR DUSTING (1930-1932)[1]

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Introduction

Experiments reported by Kightlinger (*10*), in 1924, demonstrated the possibility of controlling cereal rusts by dusting growing plants with sulphur. In 1925 Bailey and Greaney (*1*) in Manitoba, Lambert and Stakman (*12*) in Minnesota, and Kightlinger and Whetzel (*11*) in New York, obtained very effective control of rusts on cereals with sulphur dust. The Manitoba field results were very satisfactory and stimulated further interest in the practical possibility of preventing cereal rusts by dusting. The results of dusting experiments in Manitoba from 1926 to 1929, inclusive, have been reported by Bailey and Greaney (*2*) and Greaney (*7*). The present paper deals with the results of field experiments made in 1930, 1931, and 1932, at Winnipeg, Manitoba, and is a further contribution to our knowledge concerning the prevention of cereal rusts by the use of dust fungicides.

Methods and Materials

Each year of the investigation a small field of summer-fallowed clay loam soil was chosen for the experiments. The experimental field was planted to large blocks of Marquis wheat and Victory oats on May 10 and May 16, respectively. About a month after planting the blocks were divided into 1/400th acre plots. The plots were rectangular in shape and particularly suitable for hand-dusting and harvesting operations. Alleys and buffer strips of grain were left at the ends and sides of adjacent plots to serve as protection against dust drift. In 1930, 1931, and 1932, in order to insure a sufficient amount of rust infection, the grain was grown under conditions of artificially induced rust epidemics in conjunction with naturally occurring ones.

Dusting operations were commenced each year just as soon as rust appeared in the district, but not necessarily in the experimental plots. Thereafter, the plots were treated at regular intervals until the grain was beginning to ripen. Except where otherwise mentioned Kolodust, a colloidal sulphur dust, was used throughout the tests. The fungicides were applied by means of small hand-dusters which were checked at frequent intervals during the dusting season to insure reasonable accuracy and uniformity in the rate of application.

Final leaf rust readings, based on the scale of stem rust percentages adopted by the Office of Cereal Crops and Diseases, United States Department of Agriculture, were made when the leaves were still green; those for stem rust, just before the plants ripened.

The grain in the outside drill rows and at the end of each plot was removed by hand before harvest to minimize errors due to border effect.

[1] Contribution No. 388 from the Division of Botany, Experimental Farms Branch, Department of Agriculture, Ottawa, Canada. Paper delivered before the Canadian Phytopathological Society at the World's Grain Exhibition and Conference, Regina, Sask., July 27, 1933.

[2] Plant Pathologist.

The yield results were then obtained by harvesting and threshing each plot separately. Weight per measured bushel was ascertained by bulking the threshed grain of each replicated series and weighing according to Canadian Grain Standards. The correct marketable grade of each treatment was determined by officials of the Western Grain Inspection Division, Winnipeg, Manitoba.

The present experiments were planned with consideration of the intimate relation which must exist between the arrangement of the experiment and the statistical analysis of the data. The Latin Square plan of randomized experiment was used, and the analysis of variance method devised by Dr. R. A. Fisher was employed in analyzing the rust, grain quality and yield data. A complete discussion of the analysis of variance method is given by Fisher (*3*), and full details in the practical application of the method will be found in papers by Fisher and Wishart (*4*), Goulden (*5*, *6*), and Immer (*8*, *9*). The significance of the difference between the variance for dust treatments and the variance for error was determined by the z test developed by Fisher (*3*). In the interpretation of the experimental results the 5% point (20 : 1 odds) is taken as a convenient minimum level of significance.

The standard error is the measure of variation used in this study. In comparing the differences observed between any two treatments, differences of less than three times their standard error are ascribed to chance; differences as great or greater than these are considered significant and ascribed to such dusting effects as the experiments were designed to examine.

Experimental Results

OBSERVATIONS ON THE SEVERITY OF RUST EPIDEMICS

Destructive epidemics of stem rust of both wheat and oats (*Puccinia graminis* Pers.) occurred in 1930 at Winnipeg, Manitoba. In that year leaf rust of wheat (*Puccinia triticina* Erikss. and Henn.) was present, but it appeared later than stem rust and was much less severe. Crown rust of oats (*Puccinia coronata* var. *avenae* Erikss.) caused considerable damage in 1930.

Stem rust of wheat was much less destructive in 1931 than in 1930, while oat stem rust developed vigorously and reached epidemic proportions in 1931 in the experimental plots. In that year infestations of leaf rust of wheat and crown rust of oats were light and variable, so that the amount of damage caused by these diseases in 1931 was very slight.

Stem rust infection of both wheat and oats was lighter in 1932 than in the two previous years. Furthermore, the plants matured early and uniformly and escaped severe injury from these rusts. There was, however, an unusually heavy epidemic of leaf rust of wheat in 1932, at Winnipeg, and it was by far the most destructive wheat disease in that year. Light infections of crown rust occurred in the experimental plots in 1932.

In the final analysis of the results of each year rust percentages and yields of individual plots of each experiment were correlated. The significance of the correlation coefficients obtained was tested by the method

given by Fisher (3). For zero order coefficients the following formula was used:

$$t = \frac{r}{\sqrt{1-r^2}} \cdot \sqrt{n^1 - 2} \quad ,$$

where n^1 is the number of pairs entering into the correlation. The correlation coefficients for the wheat and oat dusting experiments, together with their t values, are presented in Table 1.

Table 1.—Correlation coefficients for rust and yield of wheat and oats from results of sulphur dusting experiments made in 1930, 1931, and 1932, at Winnipeg, Man.

Crop	Year	Correlation	Number of plots	Correlation coefficient	t
Wheat	1930	Stem rust and yield	144	0.9379	32.3
	1931	Stem rust and yield	84	0.8037	12.2
	1932	Stem rust and yield	97	0.5342	6.1
	1932	Leaf rust and yield	99	0.7604	11.7
Oats	1930	Crown rust and yield	86	0.8972	18.6
	1930	Stem rust and yield	86	0.8860	17.5
	1931	Stem rust and yield	64	0.4949	4.9
	1932	Stem rust and yield	86	0.5831	6.5

Significant value of t = 2.8

The results in Table 1 show the relative seasonal severity and importance of rust epidemics in 1930, 1931 and 1932, at Winnipeg, Manitoba. Owing to light infestations of leaf rust of wheat in 1930 and 1931, and of crown rust of oats in 1931 and 1932, the effect of these diseases on yield could not be determined for those years.

THE PREVENTION OF STEM RUST AND LEAF RUST OF WHEAT

The rates of sulphur dust used in the wheat dusting tests were 45, 30, and 15 pounds per acre at each application. The time intervals tested were 20, 15, 10, 5, and 2 days. Each year during the course of the investigation initial dust applications were made on July 13 when from 75 to 100% of the Marquis wheat plants were in head. Thereafter, the plants were dusted at regular intervals until the grain was beginning to ripen. The dusting period extended for 30 days in 1930, and for 36 days in 1931 and 1932.

The analysis of variance calculations for dust treatments and error, together with the z value and 5% point for each set of data analyzed, are given in Table 2. The variance in rust severity, weight per measured bushel of grain, and yield, due to dust treatments, is undoubtedly greater than the error variance, as the observed values of z exceed the 5% points. It is possible, therefore, to examine the individual treatment differences of each experiment in the light of their standard error. The results of the experiments, showing the effect of dusting on the severity of rust infection, and on the consequent yield and quality of Marquis wheat in 1930, 1931, and 1932, are given in Table 3 and presented graphically in Figure 1.

TABLE 2.—VARIANCE CALCULATIONS AND z TESTS. COMPARISON OF VARIANCE FOR RUST SEVERITY, WEIGHT PER MEASURED BUSHEL AND YIELD OF MARQUIS WHEAT, DUE TO VARIOUS SULPHUR DUST TREATMENTS, WITH THAT FOR ERROR

Year	Variable	Source of variance	Variance[1]	z[2]	5% point
Stem and leaf rust of wheat: Per cent severity					
1930	Stem rust	Treatments	2939.03	1.9897	0.3136
		Error	54.96		
1931	Stem rust	Treatments	3712.77	2.0500	0.3384
		Error	61.54		
1932	Stem rust	Treatments	5557.07	2.7089	0.3484
		Error	24.60		
1932	Leaf rust	Treatments	6214.72	2.5713	0.3484
		Error	36.31		
Quality of grain: Weight per bushel in pounds					
1930	Grain quality	Treatments	836.97	2.1651	0.3136
		Error	11.02		
1931	Grain quality	Treatments	165.93	1.9603	0.3384
		Error	2.69		
1932	Grain quality	Treatments	30.02	1.9564	0.3484
		Error	0.60		
Yield of grain: Bushels per acre					
1930	Yield	Treatments	820.14	2.4898	0.3136
		Error	5.64		
1931	Yield	Treatments	24.47	0.7153	0.3384
		Error	5.85		
1932	Yield	Treatments	293.18	1.7608	0.3484
		Error	8.66		

[1] Mean square or variance (S.D.^{2}) = $\frac{\text{Sums of squares}}{\text{Degrees of freedom}}$

[2] z=One-half the difference between the natural logarithms of the two variances, or the difference between the natural logarithms of the standard errors (standard deviations).

The results in Table 3 show clearly that stem rust and leaf rust of wheat can be effectively prevented by dusting with sulphur. In every instance there were highly significant differences in both grain quality and yield between dusted and undusted plots. The results not only show that rusts cause great reductions in yield, but indicate also that grain quality is markedly affected by these diseases.

The amount of rust infection was directly associated with yield and grain quality. The results show that the degree of rust control, and consequent improvement in yield and grain quality, is directly proportional to the rate and frequency of dust application. In general, the interval between dust applications was a more important factor in determining the effectiveness of sulphur dust than was the rate of application. Each year

TABLE 3.—SUMMARY OF RESULTS. EFFECT OF DUSTING WITH SULPHUR ON THE AMOUNT OF RUST INFECTION, AND ON THE CONSEQUENT YIELD AND QUALITY OF MARQUIS WHEAT IN 1930, 1931, AND 1932, AT WINNIPEG, MANITOBA

Year	Amount of sulphur per acre per application	0	15 lbs.					30 lbs.				45 lbs.				General Mean	Standard Error
	Interval between dust applications in days	Check	20	15	10	5	2	15	10	5	2	15	10	5	2		
1930	Total number	0	2	3	4	8	15	3	4	8	—	3	4	8	—		
1931	of dust	0	—	2	3	7	18	2	3	7	18	—	3	7	—		
1932	applications	0	—	—	—	8	18	3	5	8	18	—	5	8	13		
	Stem rust and leaf rust: Per cent severity																
1930	Stem rust	95	88	81	60	28	23	77	43	8	—	74	32	5	—	51.4	2.14
1931	Stem rust	76	—	62	59	41	18	57	57	46	10	—	56	33	—	46.8	3.20
1932	Stem rust	70	—	—	—	27	4	55	39	19	3	—	36	11	1	26.5	1.57
1932	Leaf rust	75	—	—	—	34	6	57	50	26	3	—	42	20	2	31.5	1.90
	Quality of grain: Weight per measured bushel, Canadian grade																
1930	Weight in pounds	40	42	43	55	59	60	45	53	60	—	49	60	61	—	52.4	0.96
	Grade	Feed	Feed	Feed	No. 4	1°	1°	Feed	3°	1 Hard	—	No. 6	1°	1 Hard	—	—	—
1931	Weight in pounds	52	—	54	56	61	63	56	55	62	64	—	56	62	—	58.3	0.67
	Grade	No. 5	—	No. 4	3°	1°	1 Hard	3°	3°	1 Hard	1 Hard	—	No. 4	1 Hard	—	—	—
1932	Weight in pounds	58	—	—	—	62	63	60	61	62	64	—	61	63	64	61.8	0.25
	Grade	2°	—	—	—	1°	1°	1°	1°	1°	1°	—	1°	1°	1°	—	—
	Yield of grain: Bushels per acre																
1930	Yield	6.1	7.5	8.2	14.2	20.0	25.9	9.8	18.1	27.8	—	10.7	21.7	30.4	—	16.7	0.68
	Per cent of Mean	36.5	44.9	49.1	85.0	119.8	155.1	58.7	106.4	166.5	—	64.1	129.9	182.0	—	100.0	4.07
1931	Yield	9.4	—	11.4	12.0	17.3	22.2	12.5	12.3	18.3	22.8	—	13.0	18.9	—	15.4	0.99
	Per cent of Mean	61.0	—	74.0	77.9	112.3	144.2	81.2	79.9	118.8	148.0	—	84.4	122.7	—	100.0	6.42
1932	Yield	31.0	—	—	—	42.0	46.4	36.6	40.2	44.7	48.0	—	40.2	46.1	47.3	42.3	0.93
	Per cent of Mean	73.3	—	—	—	99.3	109.7	86.5	95.0	105.7	113.5	—	95.0	109.0	111.8	100.0	2.20

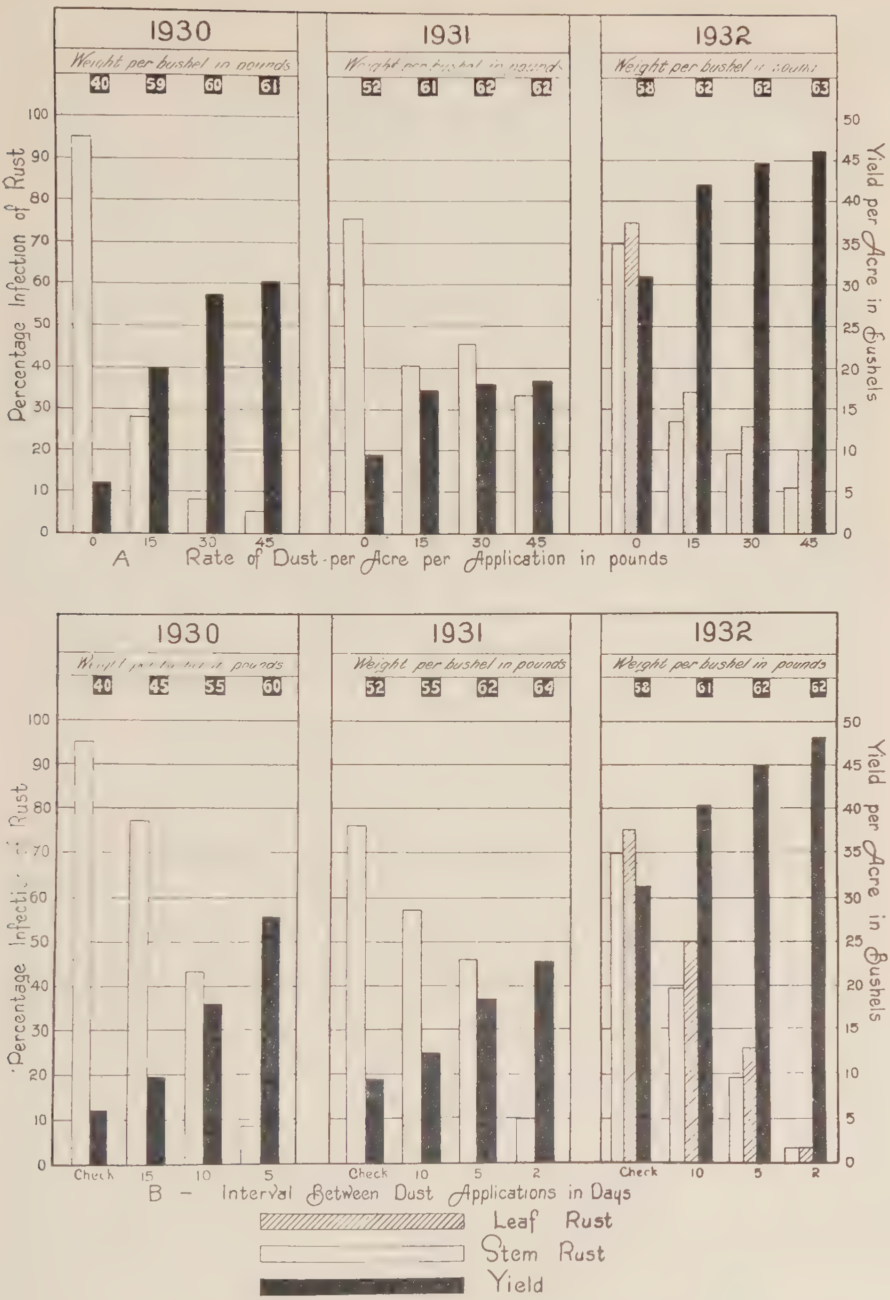

FIGURE 1. Results of sulphur dusting experiments for the prevention of stem rust and leaf rust of wheat in 1930, 1931, and 1932. Effect of rate and frequency of sulphur application on the severity of rust infection, and on the consequent yield and weight per measured bushel of grain. A. Results of dusting at different rates, and at five-day intervals. B. Results of dusting at different intervals, and at the rate of 30 pounds per acre per application.

Figure 2. Plots of Marquis wheat at Winnipeg in 1930. Left: sulphur-dusted plot. Right: check plot, not dusted, showing the effect of severe stem rust attack.

of the investigation leaf rust and stem rust of wheat were almost completely prevented by applying sulphur dust at frequent intervals (2 and 5 days) from the time the wheat plants were in the late "boot" stage until the grain was beginning to ripen.

In 1930 the yield of Marquis wheat was increased 24.3 bushels or approximately 400% by dusting, even in the presence of severe infestations of stem rust. In that year eight dust applications raised the quality of grain from "Feed", weighing 40 pounds per bushel, to "1 Northern", weighing 61 pounds per bushel. In 1931 the yield was increased over 135% by dusting. By preventing leaf rust and stem rust of wheat in 1932, dusting increased the yield 63%. A photograph of dusted and undusted plots of Marquis wheat grown at Winnipeg in 1930, is shown in Figure 2.

THE PREVENTION OF STEM RUST AND CROWN RUST OF OATS

The rates and frequencies of sulphur dust application tested in the oat dusting studies were identical with those used in the wheat experiments. In 1930 oat dusting was begun on July 16 and continued until August 22 (37 days). The dusting periods in 1931 and 1932 extended from July 12 to August 14 (32 days).

The analysis of variance calculations of rust severity, grain quality, and yield, are given in Table 4. The oat dusting schedules followed in 1930, 1931, and 1932, together with the results showing the effect of dusting on the amount of rust infection at harvest time, and on the consequent quality and yield of Victory oats, are given in Table 5 and presented graphically in Figure 3.

TABLE 4.—VARIANCE CALCULATIONS AND z TESTS. COMPARISON OF VARIANCE FOR RUST SEVERITY, WEIGHT PER MEASURED BUSHEL AND YIELD OF VICTORY OATS, DUE TO VARIOUS SULPHUR DUST TREATMENTS, WITH THAT FOR ERROR

Year	Variable	Source of variance	Variance	z	5% point
Stem and crown rust of oats: Per cent severity					
1930	Stem rust	Treatments	4494.78	2.1769	0.3484
		Error	57.79		
1930	Crown rust	Treatments	4969.38	2.3368	0.3484
		Error	46.40		
1931	Stem rust	Treatments	917.63	1.8244	0.4017
		Error	23.88		
1932	Stem rust	Treatments	3354.55	2.3625	0.3484
		Error	29.76		
Quality of grain: Weight per bushel in pounds					
1930	Grain quality	Treatments	106.48	1.6467	0.3484
		Error	2.40		
1931	Grain quality	Treatments	94.28	2.0772	0.4017
		Error	1.48		
1932	Grain quality	Treatments	43.04	1.8518	0.3484
		Error	1.06		
Yield of grain: Bushels per acre					
1930	Yield	Treatments	2049.15	1.7896	0.3484
		Error	57.24		
1931	Yield	Treatments	530.53	1.1321	0.4017
		Error	53.82		
1932	Yield	Treatments	76.04	1.0491	0.3484
		Error	9.33		

Each year during the course of the study crown rust and stem rust of oats were effectively prevented by dusting with sulphur. The effects of dusting were least with light, infrequent dustings, and greatest with heavy, frequent ones. In all the experiments the improvement in grain quality and yield was very closely associated with the degree of rust control.

Significant responses in yield were obtained from all the treatments. In 1930 the yield of Victory oats was increased 45.3 bushels per acre, or about 150%, and the weight per measured bushel of the grain was improved from 26 to 35 pounds by dusting. The increase in yield in 1931, due to rust control, was almost 100%, while an increase in yield of 15% resulted in 1932.

TABLE 5.—SUMMARY OF RESULTS.—EFFECT OF DUSTING WITH SULPHUR ON THE AMOUNT OF RUST INFECTION, AND ON THE CONSEQUENT YIELD AND QUALITY (WEIGHT PER BUSHEL) OF VICTORY OATS IN 1930, 1931, AND 1932, AT WINNIPEG, MANITOBA

Year	Amount of sulphur per acre per application	0	15 lbs.				30 lbs.				45 lbs.				General Mean	Standard Error
	Interval between dust applications in days	Check	15	10	5	2	15	10	5	2	15	10	5	2		
	Total number of dust applications	0	3	4	8	18	3	4	8	18	3	4	8	18		
	Stem rust and crown rust: Per cent severity															
1930	Crown rust	76	52	32	21	4	—	23	12	2	36	23	—	—	28.8	2.15
1930	Stem rust	62	53	27	12	3	—	10	3	1	30	17	—	—	21.8	2.40
1931	Stem rust	57	—	45	44	29	48	45	40	23	—	—	—	—	41.3	1.73
1932	Stem rust	57	—	—	21	6	—	35	17	3	40	33	11	1	22.4	1.72
	Quality of grain: Weight per measured bushel, Canadian grade															
1930	Weight in pounds	26	29	32	34	34	—	34	35	35	32	33	—	—	32.4	0.49
	Grade	2 Feed	2 Feed	1 Feed	1 Feed	1 Feed	—	1 Feed	1 Feed	1 Feed	1 Feed	1 Feed	—	—	—	—
1931	Weight in pounds	30	—	31	33	36	32	32	33	36	—	—	—	—	32.9	0.38
	Grade	2 Feed	—	2 Feed	2 Feed	2 C.W.	2 Feed	2 Feed	2 Feed	2 C.W.	—	—	—	—	—	—
1932	Weight in pounds	40	—	—	41	42	—	41	41	43	41	42	43	43	41.7	0.32
	Grade	2 C.W.	—	—	2 C.W.	2 C.W.	—	2 C.W.	2 C.W.	2 C.W.	2 C.W.	2 C.W.	2 C.W.	2 C.W.	—	—
	Yield of grain: Bushels per acre															
1930	Yield	29.5	37.9	53.5	58.1	71.8	—	62.9	64.8	74.8	54.8	60.9	—	—	56.9	2.39
	Per cent of Mean	51.8	66.6	94.0	102.1	126.2	—	110.5	113.9	131.5	96.3	107.0	—	—	100.0	4.20
1931	Yield	23.8	—	29.1	32.8	45.3	26.3	29.2	38.8	44.0	—	—	—	—	33.7	2.59
	Per cent of Mean	70.6	—	86.3	97.3	134.4	78.0	86.6	115.1	130.6	—	—	—	—	100.0	7.68
1932	Yield	56.4	—	—	62.5	63.7	—	61.4	62.1	64.9	61.6	62.5	65.6	64.0	62.5	0.97
	Per cent of Mean	90.2	—	—	100.0	101.9	—	98.2	99.4	103.8	98.6	100.0	105.0	102.4	100.0	1.55

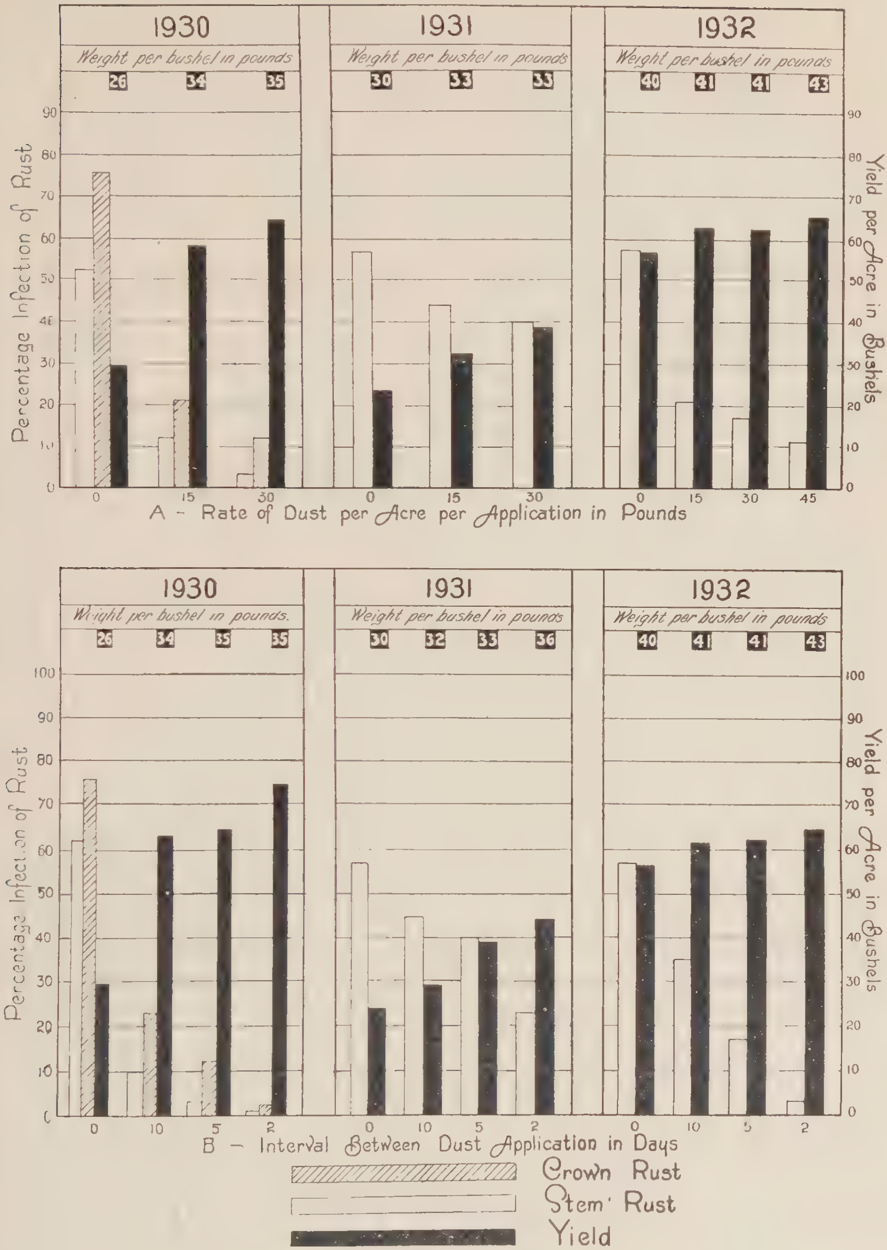

FIGURE 3. Results of sulphur dusting experiments for the prevention of stem rust and crown rust of oats in 1930, 1931, and 1932. Effect of rate and frequency of sulphur application on the severity of rust infection, and on the consequent yield and weight per measured bushel of grain. A. Results of dusting at different rates, and at five-day intervals. B. Results of dusting at different intervals, and at the rate of 30 pounds per acre per application.

In 1930, a severe rust year, the most effective rust control was achieved by applying sulphur at the rate of 30 pounds per acre at two-day intervals from July 16 to August 22. In 1931 and 1932, when stem rust was much less severe than in 1930, very effective rust control was achieved by 30-pound applications of dust at five-day intervals. From a practical viewpoint dusting at intervals of five days constitutes the most satisfactory dusting procedure. The three years' results clearly demonstrate the effectiveness and practical possibility of sulphur dusting for the control of oat rusts.

FUNGICIDAL EFFECTIVENESS OF DIFFERENT SULPHUR DUSTS

The field testing of fungicides is an important phase of any plant disease control problem. It is usually difficult, however, to test all available fungicidal dusts in the field. In the present study adequate greenhouse tests were relied upon to eliminate all but the most promising dusts for the control of cereal rusts. From a large number of dusts, therefore, five commercial brands of sulphur dust were selected for field tests.[3]

A study of the relative value of these dusts in controlling stem rust and leaf rust of wheat was made in 1930, 1931, and 1932. The dusts were applied at the rate of 30 pounds per acre at each application, and the interval between dust applications was five days. The length of the dusting period varied in different years from 32 to 38 days.

The summarized results of the analysis of variance of per cent rust severity, weight per bushel, and yield, are given in Table 6. The experimental data of the three years' dusting tests, showing the amount of rust infection, and consequent yield and quality of the grain, are summarized in Table 7.

At harvest time in 1930, 1931, and 1932, a considerable amount of rust infection was found in the dusted plots. Unfortunately, owing to the rate and frequency of application used, none of the fungicides tested gave perfect rust control. The results in Table 7 show that, for the most part, differences in rust severity between various dust treatments were quite significant, since they exceeded three times the standard error. On the other hand, differences in yield between various dusts used in these experiments were not always beyond an amount which could easily be obtained by chance. In every instance, however, rust and yield differences observed between dusted and non-dusted plots of Marquis wheat were statistically significant.

Of the dusts tested Koppers dust was the most effective fungicide in 1930, while Kolodust was decidedly better than any of the others in 1931 and 1932. The reduced efficiency of Kolodust in 1930 was due to the age of the fungicide used. Sulfodust, a medium grade of sulphur dust, although it did not afford the plants as much protection as did some of the finer and more expensive dusts, gave very satisfactory control of rust in 1931 and 1932. It is possible that the cheaper grades of sulphur dust may prove effective and economic fungicides for the control of cereal rusts.

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[3] Kolodust and Sulfodust manufactured by Niagara Sprayer and Chemical Co., Middleport, N.Y.; Electric Sulphur by Stauffer Chemical Co., Houston, Texas, U.S.A.; and Koppers Dust and Koppers Lime-Dust prepared by Koppers Research Corporation, Pittsburgh, Pa., U.S.A.

TABLE 6.—VARIANCE CALCULATIONS AND z TESTS. COMPARISON OF VARIANCE FOR RUST SEVERITY, WEIGHT PER MEASURED BUSHEL AND YIELD OF MARQUIS WHEAT, DUE TO VARIOUS DUST FUNGICIDES, WITH THAT FOR ERROR

Year	Variable	Source of variance	Variance	z	5% point
Stem rust and leaf rust of wheat: Per cent severity					
1930	Stem rust	Treatments	2340.53	2.0920	0.3484
		Error	34.26		
1931	Stem rust	Treatments	729.16	1.2718	0.4046
		Error	57.30		
1932	Stem rust	Treatments	2296.30	1.6630	0.4017
		Error	82.53		
1932	Leaf rust	Treatments	2147.10	2.0034	0.4017
		Error	39.06		
Quality of grain: Weight per measured bushel in pounds					
1930	Grain quality	Treatments	150.41	1.4752	0.3484
		Error	7.87		
1931	Grain quality	Treatments	24.16	1.3389	0.4046
		Error	1.66		
1932	Grain quality	Treatments	25.74	2.1079	0.4017
		Error	0.38		
Yield of grain: Bushels per acre					
1930	Yield	Treatments	65.91	1.6468	0.3484
		Error	3.35		
1931	Yield	Treatments	21.72	0.6912	0.4046
		Error	5.45		
1932	Yield	Treatments	78.13	1.1678	0.4017
		Error	7.56		

DISCUSSION AND CONCLUSIONS

The results of the present studies substantiate those obtained in Manitoba during the five years, 1925 to 1929, and clearly demonstrate the effectiveness of sulphur dusting for the control of cereal rusts. Leaf rust and stem rust of both wheat and oats were satisfactorily prevented in 1930, 1931, and 1932, even in the presence of severe epidemics. The data presented in this paper permit of a very accurate estimation of the amount of damage caused by cereal rusts under field conditions.

During the course of the investigation it was observed that frequent applications of sulphur dust to growing plants markedly prevented the development of wheat scab, black chaff of wheat, "smudge" of wheat, and some of the minor leaf and stem spotting diseases of both wheat and oats. As in previous studies (*7*) it was found that, although large amounts of sulphur were applied to the soil, no marked fertilizer effect occurred.

TABLE 7.—SUMMARY OF RESULTS. RELATIVE FUNGICIDAL EFFECTIVENESS OF FIVE BRANDS OF SULPHUR DUST. EFFECT OF DUSTING ON THE AMOUNT OF RUST INFECTION, AND ON THE CONSEQUENT YIELD AND QUALITY OF MARQUIS WHEAT IN 1930, 1931, AND 1932, AT WINNIPEG, MANITOBA

Year	—	Kolodust	Electric sulphur	Koppers dust	Koppers lime dust	Sulfodust	Control (no dust)	General Mean	Standard Error
	Stem rust and leaf rust of wheat: Per cent severity								
1930	Stem rust	57	63	41	57	65	95	63.0	1.85
1931	Stem rust	35	45	31	37	45	76	44.9	2.39
1932	Stem rust	17	23	31	32	26	70	33.2	2.21
1932	Leaf rust	22	27	35	35	40	77	39.3	3.21
	Quality of grain: Weight per measured bushel, Canadian grade								
1930	Weight in pounds	47	46	54	48	46	38	46.5	0.89
	Grade	6	6	5	6	6	Feed	—	—
1931	Weight in pounds	62	60	61	60	60	52	59.2	1.55
	Grade	1°	1°	1°	1°	1°	No. 5	—	—
1932	Weight in pounds	63	63	62	62	62	58	61.7	1.05
	Grade	1°	1°	1°	1°	1°	2°	—	—
	Yield of grain: Bushels per acre								
1930	Yield	8.6	10.0	15.0	10.9	8.6	5.8	9.8	0.58
	Per cent of Mean	87.7	102.0	153.1	111.2	87.7	59.2	100.0	5.92
1931	Yield	18.1	15.1	17.1	16.9	14.9	9.6	15.3	1.17
	Per cent of Mean	118.3	98.7	111.8	110.5	97.4	62.7	100.0	7.65
1932	Yield	38.6	36.9	34.6	37.0	35.2	29.5	35.3	0.97
	Per cent of Mean	109.3	104.5	98.0	104.8	99.7	83.5	100.0	2.75

In Manitoba, where the dusting period is usually from four to five weeks, there is definite evidence to show that under ordinary field conditions relatively light sulphur dust applications (30 pounds per acre), at fairly close intervals (five days), will insure effective and economic control of stem rust of both wheat and oats, and reduce, by a very significant degree, the amount of leaf rust and crown rust. Apparently, frequency of application is a much more important factor in determining the effectiveness of sulphur dust treatments than is rate of sulphur application. The results have shown that early initial dust applications prevent the accumulation of viable inoculum on the plants and thus make the subsequent control of rust relatively easy.

It is difficult to formulate sulphur dusting schedules for rust control which would be applicable in all seasons and in all regions. To a very large extent the rate and frequency of dusting will have to be decided each year and as the season advances, according to the weather conditions, the progress of the rust, the condition of plant growth, and by the degree of control achieved by previous dust applications.

At present the sulphur dusting method is recommended for the use of experimentalists, seed growers, and grain exhibitors in the grain-growing regions of Canada. Whether or not dusting for the control of cereal rusts can be made a profitable agricultural practice will depend largely on such economic factors as, relative grain prices, cost of production, cost of dust fungicides and dusting equipment. The practical possibilities of dusting would be enhanced if more intensive cultural practices were employed. On the other hand, the general introduction of commercially desirable rust resistant varieties would remove the necessity of providing protection from cereal rusts.

Summary

1. Field experiments to determine the most effective and practical method of dusting with sulphur for the control of leaf rusts and stem rusts of wheat and oats, were continued in 1930, 1931, and 1932, at Winnipeg, Manitoba.

2. Each year during the period of the experiments, relatively light applications of sulphur dust, well-timed and properly applied, almost completely controlled stem and leaf rusts of both wheat and oats. Furthermore, dusting prevented, to a marked degree, the development of some of the minor leaf and stem spotting diseases of these grain crops.

3. The effect of sulphur on the amount of rust infection, and on the consequent grain quality and yield, was least with light, infrequent dust applications, and greatest with heavy, frequent ones. In 1930, 1931, and 1932, during dusting periods of from four to five weeks, relatively light sulphur applications (30 pounds per acre), at close intervals (five days), gave very satisfactory results in preventing rusts and some of the minor diseases of both wheat and oats.

4. Yield and quality of the grain of both wheat and oats were significantly improved by dusting. In 1930, a severe rust year, the yield of Marquis wheat was increased 24.3 bushels per acre or approximately

400% by dusting, while eight 30-pound dustings improved the grain quality from "Feed" weighing 40 pounds per bushel to "1 Northern" weighing 60 pounds per bushel. By preventing rust in 1930, dusting increased the yield of Victory oats 45 bushels per acre or about 153%.

5. Of the dusts tested Kolodust, a finely-divided sulphur dust, gave the most effective rust control. The fungicidal value of sulphur increases in proportion to the fineness of the dust particles. Medium grades of sulphur dust gave very satisfactory results.

6. Sulphur dusting as a method of rust control is recommended for the use of experimentalists, seed growers, and grain exhibitors wherever destructive epidemics of cereal rusts occur.

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RESUME

Expériences sur la façon de prévenir les rouilles des céréales au moyen d'un saupoudrage de soufre (1930-1932). F. J. Greaney, Laboratoire fédéral de recherches sur la rouille, Winnipeg, Man.

Les expériences qui avaient été entreprises à Winnipeg, Manitoba, pour connaître les moyens les plus efficaces et les plus pratiques de saupoudrer avec du soufre pour prévenir les rouilles des feuilles et les rouilles de la tige de l'avoine et du blé, ont été continuées en 1930, 1931 et 1932. Chaque année, pendant la période de ces expériences, des applications relativement faibles de poussière de soufre, appliquées au moment voulu et de la bonne façon, ont presque complètement maîtrisé la rouille de la tige et de la feuille du blé et de l'avoine. En outre, le saupoudrage a empêché à un degré remarquable le développement de quelques-unes des maladies secondaires

qui tachent les feuilles et les tiges de ces récoltes de grains. L'effet du soufre sur la quantité de rouille et sur la qualité et le rendement du grain des récoltes rouillées, était au minimum lorsque les applications de poussière étaient légères et peu fréquentes, et au maximum lorsqu'elles étaient fréquentes et abondantes. En 1930, 1931, et 1932, pendant des périodes de saupoudrage de quatre à cinq semaines, des applications relativement légères de soufre (30 livres par acre), à intervalles rapprochés (cinq jours), ont donné des résultats très satisfaisants en prévenant les rouilles et quelques-unes des maladies secondaires du blé et de l'avoine. Le rendement et la qualité du grain du blé et de l'avoine ont été beaucoup améliorés par le saupoudrage. En 1930, une année à rouille très grave, le saupoudrage a augmenté le rendement du blé Marquis de 24.3 boisseaux à l'acre, soit environ 400 pour cent, et huit saupoudrages de 30 livres chacun ont amélioré la qualité du grain depuis la catégorie à bétail, pesant 40 livres par boisseau, à la catégorie "du nord No. 1" pesant 60 livres par boisseau. En empêchant la rouille en 1930, le saupoudrage a augmenté le rendement de l'avoine Victoire de 45 boisseaux par acre, soit environ 153 pour cent. De toutes les poussières à l'essai, la Kolodust, une poussière de soufre finement divisée, est celle qui a donné le contrôle le plus efficace. La valeur fongicide du soufre augmente en proportion de la finesse des particules de poussière. Les catégories moyennes de poussière de soufre ont donné des résultats très satisfaisants. Le saupoudrage au soufre, pour prévenir la rouille, est recommandé aux expérimentateurs, aux producteurs de semence, et aux exposants de grains, partout où des épidémies destructives de rouille de céréales se produisent.

LEAF AREA IN RELATION TO FRUIT SIZE AND TREE GROWTH[1]

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Introduction

Since fruit size is related directly to leaf area, as shown by Haller (*2*), Ellenwood (*1*), and Magness (*3*), it was felt that valuable information could be obtained by interpreting thinning distance in terms of leaf area per apple. Several investigators have demonstrated the relationship of leaf area to fruit size by means of ringed branches, and adjusted leaf areas, but little or no information is available concerning such a relationship under actual orchard conditions. The ringing of branches undoubtedly brings about in the limbs and their contributory root systems, abnormal physiological conditions which are bound to influence the data secured, and limit its degree of application. Accordingly, in the investigations described in this paper, the relation between leaf area and fruit development has been studied on trees growing naturally under normal orchard conditions.

Experimental Material

The orchard of which the experimental trees form part, is situated on a flat bench gently sloping from west to east. The soil conditions are not of the best as the land is underlaid with gravel, which rises within two feet of the surface in some parts of the orchard. In an endeavour to compensate for the original handicap, special attention has been paid to building up the soil by means of leguminous cover crops. A determined effort has also been made to secure adequate and uniform distribution of irrigation water. This system of orchard management has resulted in healthy vigorous trees, which, for the most part, exceed average growth dimensions for their age.

The trees employed in this experiment are seventeen years old and for the past thirteen years have been used for a systematic test of various thinning practices. The orchard consists of two rows of trees of each of the four varieties, McIntosh, Delicious, Rome Beauty and Newtown. In each row there is a systematic distribution of heavily, medium, and lightly thinned trees. The systematic distribution of thinning treatments has been such as to overcome, as far as possible, any error due to soil differences. By "heavy" thinning is meant that the apples were spaced nine inches apart, by "medium" thinning, six inches apart, and by "light" thinning, three inches apart, provided there were sufficient fruiting spurs to permit of this spacing. In no case was more than one apple left to a spur. The thinning treatments have been applied annually to the same individual trees, so that it is now possible to study any cumulative effects that thirteen years of thinning may have produced.

[1] This paper constitutes a report on one phase of a comprehensive apple thinning investigation in progress at the Dominion Experimental Station, Summerland.

[2] Student attached to the staff of the Dominion Experimental Station, Summerland.

FIGURE 1. The "Integrator" in use.

METHODS OF PROCEDURE

Large limbs have been selected for measurement of leaf areas per apple, so as to be able to depict, with as little error as possible, the actual relationships existing in the entire trees employed in this experiment. In each variety studied, three branches have been used, representative of the three thinning treatments applied. An attempt has been made to select

on the experimental trees, branches carrying a maximum and uniformly distributed crop, according to the degree of thinning received, in order that results may be compared on an equitable basis.

The areas of the leaves have been measured on the branches by means of a small device known as an "integrator", which has been described by Vyvyan and Evans (*41*). This device consists of two plates, 10 cms. square, attached to the jaws of a strong paper clip. A slight pressure with the thumb and finger on the paper clip opens the jaws, permitting a leaf to be inserted between the plates. Releasing the pressure on the clip permits the jaws to close, flattening the leaf between the two plates. The upper plate is heavy glass, and is graduated in square centimeters, which facilitates rapid measurement of the leaf surface. A person experienced in the use of the integrator can measure, with an assistant to record the data, 400 to 500 leaves per hour. Figure 1 shows the integrator in use.

Presentation of Results

The areas of individual leaves were found to range between 1 and 76 square centimeters, while the averages ranged between 10 and 15 square centimeters. Table 1 shows the number of leaves, leaf size and leaf area per apple for four varieties of apples thinned to three different distances.

Table 1.—Number of leaves, leaf size, and leaf area per apple

Variety	Thinning distance, inches	No. of apples	No. of leaves	No. of leaves per apple	Leaf area per apple, sq. cm.	Average leaf size, sq. cm.
McIntosh	9	58	3525	61.00	813.50	13.35
	6	45	1883	41.00	524.38	12.54
	3	112	2790	25.00	314.50	12.63
					Average	12.84
Delicious	9	90	4867	54.10	663.10	12.17
	6	122	3905	32.00	318.00	9.95
	3	76	1974	26.15	299.30	11.15
					Average	11.09
Rome Beauty	9	99	2847	27.89	380.50	13.21
	6	68	1599	23.50	260.00	11.06
	3	127	2526	19.90	241.90	12.15
					Average	12.14
Newtown	9	105	2281	21.75	285.60	13.13
	6	134	2184	16.28	235.00	14.41
	3	141	2154	15.27	220.60	14.46
					Average	14.00

With all four varieties it is evident that leaf area per apple increased as thinning severity increased. This result is to be expected since heavy thinning allows a greater number of leaves and a greater leaf surface per apple than does light thinning. However, it is interesting to note that difference in leaf area per apple between lightly and heavily thinned branches was influenced by variety. Thus, with McIntosh, the leaf area per apple was nearly three times greater on the heavily thinned than on

the lightly thinned branch, while with Rome Beauty, the leaf area per apple was only one and one-half times greater in the case of the heavily thinned branch. Newtown showed a still smaller difference. It seems necessary to assume, therefore, that differences in leaf area per apple must be influenced by some factor or factors operating apart from the differences caused by the distance of thinning itself.

Density of the foliage carried by the tree is one important factor influencing leaf area per apple. This factor is an inherent characteristic fluctuating from variety to variety. Thus, it is a well known fact, fully substantiated by the data secured in this experiment, that Delicious has smaller leaves and fewer of them than does McIntosh. Another factor that influences leaf area per apple is the manner in which a variety sets its fruit. McIntosh and Newtown being subject to what is known as "biennial bearing" usually produce an extremely heavy crop one year and an extremely light one the next. This is in direct contrast with varieties like Rome Beauty and Delicious which tend to produce a medium crop, year in and year out. Thus, it is difficult to compare the leaf area per apple of McIntosh and Newtown with that of Rome Beauty and Delicious, because with the first two varieties, a maximum crop is borne in the bearing year, while with the other two a medium but unevenly distributed crop is carried by the tree every year. However, as previously stated, an attempt has been made to overcome this difficulty by selection of limbs carrying a full load.

The difference in leaf area per apple between 9- and 6-inch thinned branches was, in every case, greater than the corresponding difference between 6- and 3-inch thinned branches. This can be attributed at least in part to the fact that 3- and 6-inch thinning consisted mainly in thinning out similarly spaced clusters of fruit, while 9-inch thinning resulted in the removal of some of these clusters entirely. This was found to be especially true of the Rome Beauty variety.

The average size of the leaves in a given variety varied slightly with the thinning treatments applied, larger leaves tending to occur with heavier thinning. Newtown had the largest sized leaves of any variety studied, although the density of the foliage, when measured by the number of leaves per apple, was the least of any variety examined. McIntosh, on the other hand, while rating only second highest in size of leaf, by far exceeded any other variety, in both the number of leaves, and the average leaf surface per apple. This probably explains why McIntosh can mature to marketable size a far heavier crop of fruit than almost any other variety.

The relation of thinning distance, leaf area and fruit size is of especial interest in connection with Delicious, since it has been demonstrated at this station that heavy thinning of this variety has been profitable due to greater returns resulting from larger and better coloured fruit. The data presented in Table 1 suggest that this increase in size from heavy thinning is due to an increase in leaf area per fruit. It will be noted that by heavy thinning, leaf area was increased by 363 square centimeters per apple, or more than double that of light thinning. In the case of Rome Beauty, leaf surface per apple was surprisingly low in every instance. This was

hardly to be expected, since this variety matures unusually large-sized fruits. The explanation may lie in greater photosynthetic efficiency of Rome Beauty leaves, and in the utilization of a greater proportion of the manufactured food for fruit production, as opposed to wood growth in this variety, than was the case with the other varieties studied. Additional data bearing on this point are presented in Table 2.

Since it was desired to discover whether there was any significant difference in the photosynthetic efficiency of the leaves of the different varieties, the weight as well as the number of apples harvested from each experimental limb was recorded at picking. The weight of the apples harvested was divided by the number of apples on each experimental limb, and hence the average weight per apple obtained. This was found to increase progressively as the severity of thinning increased. The varieties maturing the largest sized fruit were McIntosh and Rome Beauty.

TABLE 2.—WEIGHT PER APPLE AT HARVEST, AND WEIGHT OF FRUIT PRODUCED PER 100 SQUARE CENTIMETERS OF LEAF AREA

Variety	Thinning distance, inches	Average weight per apple at harvest, lb.	Weight of fruit produced per 100 sq. cm. leaf area, lb.	Average, lb.
McIntosh	9	0.433	0.0532	
	6	0.344	0.0657	
	3	0.336	0.1068	
				0.0752
Delicious	9	0.385	0.0582	
	6	0.291	0.0915	
	3	0.294	0.0983	
				0.0827
Rome Beauty	9	0.416	0.1095	
	6	0.303	0.1166	
	3	0.256	0.1050	
				0.1104
Newtown	9	0.247	0.0865	
	6	0.225	0.0958	
	3	0.172	0.0780	
				0.0868

From the data presented in Table 2, it is apparent that Rome Beauty produced by far the greatest weight of fruit per unit of leaf area. This suggests that the photosynthetic efficiency of Rome Beauty may be greater than that of other varieties. In fact, Rome Beauty, being an annual bearer, may possess still greater photosynthetic activity than the results would indicate, since this variety not only produces a large amount of fruit with a relatively small leaf area, but is able to synthesize sufficient surplus food to develop a new set of fruit buds for the following season.

It is interesting to note (Table 2, column 3) that the weight of fruit produced by 100 square centimeters leaf area was by no means constant, even within the varieties themselves. Thus, in McIntosh and Delicious,

100 square centimeters of leaf surface produced a much smaller weight of fruit on the heavily thinned than on the medium and lightly thinned branches. If we assume that the photosynthetic efficiency of the leaves in a given variety is a constant, we may postulate that in the case of the heavily thinned trees more food has been translocated back to feed the tree than in the case of the medium or lightly thinned trees, because in the latter instance the greater volume of fruit produced has demanded a relatively greater supply of food. Data supporting this assumption are presented in Table 3.

After twelve years of systematic thinning involving the same trees each year, heavily thinned trees have grown on the average, a significantly greater amount than lightly thinned trees. This is especially true of the varieties McIntosh and Delicious whose growth records are shown in Table 3.

TABLE 3.—TRUNK CROSS-SECTIONAL AREAS OF DIFFERENTLY THINNED TREES

Variety	Area of trunk cross-section in square inches		
	9-inch thinning	6-inch thinning	3-inch thinning
Delicious	124.1	104.6	99.9
McIntosh	156.2	124.7	122.6
Rome Beauty	96.0	93.4	81.0
Newtown	98.8	95.8	93.2

In the varieties Rome Beauty and Newtown there appeared to be relatively little differential effect in the amount of apple tissue produced by a given leaf area on the differently thinned branches. Similarly, in the trunk measurements just presented, it will be seen that the difference in tree growth between lightly and heavily thinned trees is not nearly so striking as in the case of McIntosh and Delicious.

The fact that, of the four varieties studied, Rome Beauty has produced the smallest trees, lends weight to the suggestion that in this variety a comparatively large percentage of the manufactured food is used in the production of fruit, leaving less to be translocated to other parts of the tree.

SUMMARY

1. The leaf area per apple was determined on three differently thinned branches of each of the varieties McIntosh, Delicious, Rome Beauty and Newtown.

2. McIntosh and Delicious had the densest foliage, and Rome Beauty and Newtown the lightest.

3. Newtown had the largest leaves, followed by McIntosh, Rome Beauty and Delicious.

4. The size of fruit was positively correlated with leaf area per apple.

5. In each variety the weight of fruit produced per 100 square centimeters leaf area was determined. This was found to be least in the case of McIntosh and greatest in the case of Rome Beauty. It is suggested that these results may be due to differences in photosynthetic efficiency of the leaves.

6. Heavily thinned trees grew more than lightly thinned trees. It is suggested that in the former case more synthesized food materials were available to be translocated back into the tree.

Acknowledgments

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RESUME

Rapports entre la superficie des feuilles, la grosseur des fruits et la pousse de l'arbre. D. V. Fisher, Station expérimentale fédérale, Summerland, C.-B.

L'étendue de feuilles par pomme a été déterminée sur trois branches éclaircies de façons différentes de chacune des variétes McIntosh, Délicieuse, Rome Beauty, et Newtown. Les McIntosh et Délicieuse avaient le feuillage le plus épais, et les Rome Beauty et Newton, le feuillage le plus clair. La grosseur des fruits était clairement reliée à l'étendue en feuilles par pomme. On a constaté que le poids des fruits produits par 100 cm. c. de l'étendue en feuilles était moindre pour la McIntosh et plus grand pour la Rome Beauty. Les résultats donnent à croire qu'il existe une différence dans l'efficacité photo-synthétique des feuilles de différentes variétés. Les arbres soumis à un fort éclaircissage se sont mieux développés que les arbres légèrement éclaircis, ce qui donne à croire qu'il existait, chez les premiers, plus de principes fertilisants synthétisés pour être retransportés dans l'arbre.

THE ECONOMIC SITUATION

PREPARED IN THE AGRICULTURAL ECONOMICS BRANCH, DEPARTMENT OF AGRICULTURE, OTTAWA, FROM BASIC DATA COLLECTED BY THE DOMINION BUREAU OF STATISTICS

The index number of wholesale prices in Canada computed by the Dominion Bureau of Statistics was 72.0 in March as compared with 72.1 in February. Among the sub-indexes, those of vegetable products; fibres, textiles and textile products; wood, wood products and paper; iron and its products; non-metallic minerals and their products; and chemicals and their products advanced. Animals and their products, and non-ferrous metals and their products declined.

Retail Prices.—The total index of retail prices and costs of services advanced one point in March, the index of food prices rising from 69.4 to 72.9. There was a slight recession in the clothing index.

Employment.—The seasonally adjusted index of employment in Canada was 96.7 at the first of April as compared with 97.4 at the first of March. In manufacturing industries there was a distinct gain, but in the mining, construction, and maintenance groups there were declines.

Physical Volume of Business.—The physical volume of business showed a distinct gain in March, when the index rose to 93.1. Industrial production advanced from 84.0 in February to 92.0 in March. Among the sub-indexes mineral production rose sharply from 117.2 to 149.0. Nickel, zinc and gold reached new high points; in fact, only the production of silver was lower than in the preceding month. Manufacturing showed a substantial increase for which food stuffs, automobile production, imports of textiles and petroleum, and newsprint production were chiefly responsible. Output of newsprint reached the highest figure since October, 1930. Carloadings advanced and exports in general were considerably above those in the previous month.

Agricultural Products.—The index of wholesale prices of Canadian farm products receded to 56.5. The index of prices of grains rose fractionally to 49.5, largely because of somewhat higher values for wheat and hay. The index of animal products, however, fell from 72.5 to 68.3. This decline was primarily due to lower prices for hogs, calves, eggs, wool, hides, and skins. Agricultural marketings were, on the whole, lower in March than was the case in February; the index thus receded from 67.1 to 63.8. The index of grain marketings declined from 66.4 to 58.7. The movement of wheat was slightly above that for February, but shipments of oats, barley, flax, and rye were unusually low. Live stock marketings declined from 94.0 to 86.4. The index of cattle marketings receded from 88.4 to 86.4. Hog marketings stood at 81.2 as compared with 88.6 in February.

Cold Storage Holdings.—The index of cold storage holdings fell to 97.0 at March 1 and dropped to 84.2 at April 1, which indicates the continuance of a more rapid movement of goods into consumption.

The Situation in General.—During the first three months of 1934 the index of wholesale prices rose about 2 points. Prices of farm products advanced sharply in February but eased off again in March. The advance was largely due to a rise in prices of animal products because the index of prices of field products has shown only a moderate gain. Retail prices tended toward higher levels. The index numbers of prices in general are well above those of a year ago. The physical volume of business showed a substantial gain. Agricultural marketings have been relatively light, cold storage holdings declined during the first quarter of 1934 and were considerably lower than those in the first three months of 1933.

ANNUAL AND MONTHLY INDEX NUMBERS OF PRICES AND PRODUCTION COMPUTED BY DOMINION BUREAU OF STATISTICS

Year	Wholesale Prices 1926 = 100				Retail prices and cost of services (5)	Production (6) 1926 = 100			
	All commodities (1)	Farm products (2)	Field products (3)	Animal products (4)		Physical volume of business	Industrial production	Agricultural marketings	Cold Storage holdings
1913	64.0	62.6	56.4	77.0	65.4				
1914	65.5	69.2	64.9	79.0	66.0				
1915	70.4	77.7	76.9	79.2	67.3				
1916	84.3	89.7	88.4	92.3	72.5				
1917	114.3	130.0	134.3	119.6	85.6				
1918	127.4	132.9	132.0	134.7	97.4				
1919	134.0	145.5	142.4	152.5	107.2	71.3	65.5	48.1	47.1
1920	155.9	161.6	166.5	149.9	124.2	75.0	69.9	52.6	94.2
1921	110.0	102.8	100.3	108.5	109.2	66.5	60.4	65.2	86.4
1922	97.3	86.7	81.3	99.1	100.0	79.1	76.9	82.6	82.8
1923	98.0	79.8	73.3	95.1	100.0	85.5	83.8	91.4	87.6
1924	99.4	87.0	82.6	97.2	98.0	84.6	82.4	102.5	114.9
1925	102.6	100.4	98.1	105.7	99.3	90.9	89.7	97.2	108.6
1926	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.9	100.0
1927	97.7	102.1	99.9	105.7	98.4	106.1	105.6	103.6	110.0
1928	96.4	100.7	92.6	114.3	98.9	117.3	117.8	146.7	112.8
1929	95.6	100.8	93.8	112.5	99.9	125.5	127.4	101.1	109.6
1930	86.6	82.3	70.0	102.9	99.2	109.5	108.0	103.0	128.4
1931	72.2	56.3	43.6	77.6	89.6	93.5	90.4	99.0	125.7
1932	66.7	48.4	41.1	60.7	81.4	78.7	74.0	114.3	120.1
1933									
Jan.	63.0	43.6	35.1	57.9	79.1	68.1	62.2	56.1	112.0
Feb.	63.6	43.0	36.0	54.7	78.4	67.0	60.0	76.5	127.6
Mar.	64.4	44.7	38.0	56.0	77.8	68.4	62.5	129.0	135.8
April	65.4	46.8	41.1	56.4	78.1	69.8	65.1	104.1	112.7
May	66.9	51.2	46.9	58.4	77.0	76.4	72.7	95.4	110.4
June	67.6	52.6	49.4	57.9	77.0	82.2	79.8	221.9	119.9
July	70.5	60.1	60.8	59.0	77.2	84.1	82.6	221.9	119.9
Aug.	69.4	57.0	54.9	60.5	78.6	89.8	89.5	197.2	114.2
Sept.	68.9	54.7	49.5	63.4	78.8	90.8	90.2	101.1	115.7
Oct.	67.9	51.4	44.6	62.8	77.9	88.2	87.4	70.5	112.7
Nov.	68.7	53.8	46.7	65.8	78.1	85.5	83.9	41.8	111.1
Dec.	69.0	53.3	45.3	66.6	78.4	86.2	85.1	30.7	107.6
1934									
Jan.	70.6	55.3	47.9	67.8	78.7	86.8	84.5	48.2	108.1
Feb.	72.1	58.0	49.3	72.5	79.2	86.4	84.0	67.1	98.6
Mar.	72.0	56.5	49.5	68.3	80.2	93.1	92.0	63.8	97.0

1. See Prices and Price Indexes 1913-1928, pp. 19-21, 270-289 and 1913-1931, p. 15.
2. Wholesale prices of Canadian products of farm origin only. See Prices and Price Indexes 1913-1931, p. 33, and Monthly Mimeographs 1932 and 1933.
3. Wholesale prices of grains, fruits and vegetables.
4. Wholesale prices of Animals and Animal Products.
5. Including foods, rents, fuel, clothing and sundries, See Prices and Price Indexes 1913-1928, pp. 181-185, 290-293. 1926 = 100.
Prices and Price Indexes 1913-1931, p. 122, and Monthly Mimeographs 1932-1933.
6. Monthly Review of Business Statistics, p. 8, and Monthly Indexes of the Physical volume of business in Canada, supplement to the Monthly Review of Business Statistics, November, 1932.

Imports and Exports.—Imports into Canada in January, 1934, amounted to $32,391,000 as compared with $24,441,133 in January, 1933. In February, 1934, imports were valued at $33,592,000 as compared with $23,514,000 in the same month in 1933. In March of this year imports were valued at $47,497,000, while in March last year the figure was $32,963,000.

Comparing exports in the same period, those in January, 1934, amounted to $46,652,000 as compared with $31,562,000 in January, 1933. The figures for February were $37,842,000 and $26,397,000 respectively, while in March, 1934, exports were valued at $57,662,000 as against $36,579,000 in March, 1933.

From an agricultural point of view the wheat situation is probably most serious. Large crops in importing countries and low purchasing power have affected demand more than quotas established under the World Wheat Agreement. In this connection "The Monthly Review of the Wheat Situation", April 23, 1934, published by the Dominion Bureau of Statistics, states: "World trade in wheat continues on a small scale. From August 1, 1933, to April 16, 1934, world shipments of wheat and flour amounted to 378 million bushels as compared with shipments of 456 million bushels during the corresponding period in the previous cereal year. The London Wheat Conference estimated world import demand at 560 million bushels. On this basis a balance of 182 million bushels remains to be shipped during the remaining 15 weeks of the crop year. It would appear that a noticeable improvement in demand must take place if importing countries are to require 560 million bushels during 1933-34."

In the industrial situation one unfavourable factor may be noted, namely, that the construction index has risen but little in March. This affects the building trades and allied industries.

LA SITUATION ECONOMIQUE

PREPARE PAR LA DIVISION DE L'ECONOMIE AGRICOLE DU MINISTERE DE L'AGRICULTURE, OTTAWA, ET BASE SUR LES DONNEES RECUEILLIES PAR LE BUREAU FEDERAL DE LA STATISTIQUE

Le chiffre indice des prix de gros au Canada, computé par le Bureau fédéral de la Statistique, était de 72.0 en mars contre 72.1 en février. Parmi les sous-indices, ceux des produits végétaux, des fibres, des textiles et des produits textiles, du bois, des produits du bois et du papier, du fer et ses produits, des minéraux non métalliques et leurs produits, et des ingrédients chimiques et leurs produits ont monté; ceux des animaux et leurs produits et des métaux non ferreux et leurs produits ont baissé.

Prix de détail.—L'indice total des prix de détail et des frais de services est monté d'un point en mars, l'indice des prix des aliments est passé de 69.4 à 72.9. Il y a eu une légère diminution dans l'indice des vêtements.

Embauchage.—L'indice de l'embauchage au Canada, ajusté pour la saison, était de 96.7 au 1er avril contre 97.4 au 1er mars. Il y a eu un gain considérable dans l'industrie manufacturière, mais des baisses dans les industries minières, de construction et d'entretien.

Volume physique des affaires.—Le volume physique des affaires a enregistré un gain net en mars, lorsque l'indice s'est élevé à 93.1. La production industrielle est passée de 84.0 en février à 92.0 en mars. Parmi les sous-indices, la production minérale s'est élevée brusquement de 117.2 à 149.0. Le nickel, le zinc et l'or ont atteint de nouveaux points élevés; en fait, seule la production de l'argent était plus faible que celle du mois précédent. L'industrie manufacturière a révélé une augmentation considérable, qui était due principalement aux denrées alimentaires, à la production des automobiles, aux importations de tissus et de pétrole, et à la production de papier à journaux. La production de ce papier a atteint le plus haut chiffre depuis le mois d'octobre 1930. Les chargements de wagons ont augmenté et les exportations en général étaient bien supérieures à celles du mois précédent.

Produits agricoles.—L'indice des prix de gros des produits de ferme canadiens est tombé à 56.5. L'indice des prix des grains s'est élevé d'une fraction à 49.5, surtout à cause d'une légère augmentation des prix du blé et du foin. Par contre, l'indice des produits animaux est tombé de 72.5 à 68.3, principalement à cause d'une diminution de prix sur les porcs, les veaux, les œufs, la laine, les cuirs et les peaux. Tout considéré, les ventes de produits agricoles en mars ont été inférieures à celles de février, et l'indice a diminué de 67.1 à 63.8. L'indice des ventes de grains a baissé de 66.4 à 58.7. Le mouvement du blé a été légèrement supérieur à celui de février, tandis que les expéditions d'avoine, d'orge, de lin et de seigle

étaient très basses. Les ventes de bestiaux ont baissé de 94.0 à 86.4. L'indice des ventes de bovins a baissé de 88.4 à 86.4. Les ventes de porcs étaient à 81.2 contre 88.6 en février.

Produits conservés au froid.—L'indice des produits frigorifiés, qui était à 97.0 au 1er mars est tombé à 84.2 au 1er avril, ce qui indique que les produits entrent plus rapidement en consommation.

La situation en général.—Pendant les trois premiers mois de 1934 l'indice des prix de gros s'est élevé de 2 points. Les prix des produits agricoles ont monté brusquement en février pour redescendre en mars. La hausse était due principalement à un gain dans les prix des produits animaux parce que l'indice des prix des produits des champs n'accusait qu'un gain modéré. Les prix de détail tendaient à monter à des niveaux plus élevés. Les indices des prix en général étaient bien supérieurs à ceux de l'année précédente. Le volume physique des affaires accusait un gain substantiel. Les ventes agricoles ont été relativement faibles, la quantité de produits frigorifiés a diminué pendant le premier trimestre de 1934 et elle était bien inférieure à celles des trois premiers de 1933.

Importations et exportations.—En janvier 1934, les importations au Canada se sont chiffrées par $32,391,000 contre $24,441,133 en janvier 1933. En février 1934, les importations étaient évaluées à $33,592,000 contre $23,514,000 pendant le même mois en 1933. En mars de cette année, les importations étaient évaluées à $47,-497,000, tandis qu'en mars l'année dernière elles étaient à $32,963,000.

Si nous comparons les exportations pendant la même période, celles de janvier 1934 se sont montées à $46,652,000 contre $31,562,000 en janvier 1933. Les chiffres pour février étaient de $37,842,000 et $26,397,000 respectivement, tandis qu'en mars 1934, les exportations étaient évaluées à $57,662,000 contre $36,579,000 en mars 1933.

Au point de vue agricole la situation du blé est peut-être des plus sérieuses. Les grosses récoltes dans les pays importateurs et le faible pouvoir d'achat ont affecté la demande plus que les contingentements établis sous l'accord mondial du blé. Sous ce rapport, «La revue mensuelle de la situation du blé» (23 avril 1934), publiée par le Bureau fédéral de la Statistique, dit ce qui suit: «Le commerce mondial du blé continue sur une petite échelle. Entre le 1er août 1933 et le 16 avril 1934, les expéditions mondiales de blé et de farine se chiffraient par 378 millions de boisseaux, contre une quantité de 456 millions de boisseaux pendant la période correspondante de l'année précédente de céréales. La Conférence du blé de Londres estimait que les besoins d'importation pour le monde entier étaient de 560 millions de boisseaux. Sur cette base, il restait à expédier un reliquat de 182 millions de boisseaux pendant les quinze semaines restantes de l'année de récolte. Il semble qu'il faudra qu'une amélioration considérable se produise pour que les pays importateurs puissent prendre 560 millions de boisseaux en 1934-33.»

En ce qui concerne la situation industrielle, un facteur défavorable est à noter, c'est l'indice de la construction qui n'a fait que peu de progrès en mars. Ceci affecte les industries du bâtiment et les industries qui s'y rattachent.

ANNUAL CONVENTION DATES

The annual convention of the Canadian Society of Technical Agriculturists is being held at Macdonald College and at the Oka Agricultural Institute at La Trappe, P.Q., from Monday, June 25 to Thursday, June 28. The annual convention of the Canadian Seed Growers' Association will be held at the same institutions and on the same dates.

During Monday, Tuesday and Wednesday mornings at Macdonald College the various groups and societies affiliated and co-operating with the C.S.T.A. will hold their business and technical sessions. These include the Canadian Phytopathological Society, the Canadian Society of Agricultural Economics, the Canadian Society of Animal Production (Eastern Section), the Horticultural Group, the Soils Group, and the Agricultural Engineering Group of the C.S.T.A.

The Hemlock Looper

Eggs on the twigs

Pupa (natural size)

Caterpillars (nat. size)

Moth (nat. size)

Infested twig,
early feeding

A looper outbreak, balsam forest

Infested twig, end
of feeding